FLOWERING PLANTS
THEIR STRUCTURE AND HABITAT

CHARLOTTE L. LAURIE

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FLOWERING PLANTS

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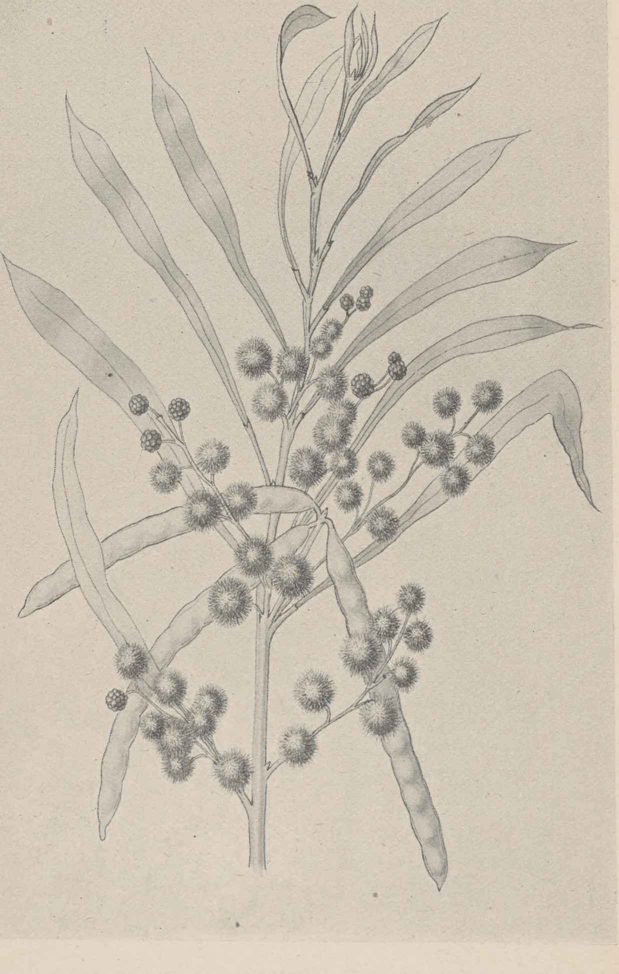

PLATE V.

FIG. 80.—ACACIA.

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FLOWERING PLANTS

Their Structure and Habitat

BY

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PREFACE

This little book is an attempt to interest students of Botany in the habitat of plants, a branch of Nature Study which has been almost neglected in the more definite teaching of Botany in schools.

Part I. deals with the problems that belong to Ecology, the science that investigates everything relating to the habitat of plants or animals. And here it must be stated that only the most general conclusions have been given—exception to the statements made will occur to every botanist—for it must be remembered that the presence of a plant in a particular locality depends on so many circumstances, many of which have not been as yet fully investigated, that it is often only possible to make very general statements. Another difficulty of the subject is that a given structure in plants does not necessarily denote similarity of environment. This is well seen in the case of hairiness, which is usually an adaptation of structure on the part of the plant to dryness of surroundings; but there are many very hairy plants, such as Comfrey, growing in anything but dry situations.

Part II. treats of the minute structure of the plant and its adaptations to its habitat. It is the root, stem, and, above all, the leaf, that are capable of adapting themselves to environment; the structure of these vegetative organs is therefore given in detail; that of the flower is less fully treated.

Part III. gives certain Natural Orders, special attention being paid to their ecological characteristics.

An elementary knowledge of Botany, such as that contained in my "Text-Book of Elementary Botany," is here assumed: the two books will be found to cover the ground required by the London Matriculation, the Senior Oxford, the Higher Kindergarten, Advanced South Kensington, and other Examinations. The new syllabuses of these Examinations rightly lay much stress on the practical observation of plant life, and it is hoped that this book will prove helpful in this branch of Nature Study.

With regard to the illustrations, it is only necessary to say that they have been done especially for this book by Miss W. L. Boys-Smith, whose work in the "Elementary Botany" has been so widely commended. I am much indebted to her for all the trouble she has taken, especially with the Histology section.

Lastly, I wish to express my thanks to all those—too numerous to mention—who in various ways have kindly helped me, more particularly to Miss Margery Reid, B.Sc., for special help with Part I., and permission to use her map illustrating the distribution of plants, and to Miss Amy Johnson, B.Sc., without whose constant assistance I should scarcely have ventured to write this book. She has carefully read over all the proof-sheets, and her suggestive criticism has been invaluable.

To the kindness of Mr. G. W. Hedley, of Cheltenham College, I am indebted for very useful lists of plants and their habitats; his list of water-plants found in Coombe Hill Canal is given in Appendix B.

CHARLOTTE L. LAURIE.

CHELTENHAM.
September, 1903.

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PART I

PLANT ECOLOGY

FLOWERING PLANTS:
THEIR STRUCTURE AND HABITAT

CHAPTER I

INTRODUCTION TO PLANT ECOLOGY

Scope of Ecology. PLANT Ecology (Gk. *oikos*, a house, and *logos*, a discourse) is the science which treats of everything relating to the habitat of plants. It investigates the exact physical conditions under which the plants of a given area are living; it notes the adaptation of their organs to these external conditions; and, lastly, it determines what plants, through their power of response to similar conditions, grow together and are thus associated with each other.

Physical Conditions. The physical features of a country or district are of primary importance in this study, for it will be found that the plants which grow together, forming the vegetation of the district in question, are those which either require the same conditions or can adapt themselves to them. From this point of view the most important physical features are:

1. The amount of moisture and, connected with this, the porosity of the soil.
2. The duration and intensity of light.
3. The temperature.

These, to a certain extent, depend on the latitude and altitude of the district. The latitude and altitude of a country or district help to determine its vegetation. Thus the vegetation of the tropics is, speaking broadly, different from that of the temperate zone, which in its turn differs from that of the arctic regions. This is due to the difference in temperature, which, other things being constant, varies with the latitude. The altitude, or the height above the sea-level, may neutralize the effect of latitude. This partly accounts for a vegetation similar to that of temperate regions being found on tropical mountains of a certain elevation. At the same time, this is not the whole of the explanation. The fact of temperature varying with latitude accounts for the possibility of alpine plants being able to live in tropical regions, but it does not explain their origin in those latitudes. To understand that, some knowledge of the climatic changes in past ages is necessary, and is more fully discussed later (Chapter III.).

The rainfall of a country and the amount of water present in any form, as dew, snow, mist, fog, or sleet, is of great importance. In certain parts of the tropics, where there are two seasons—the dry and the rainy—and where the dew at nights is heavy even in the dry season, the vegetation is luxuriant. In the same latitudes, where, instead of an abundant rainfall, there is practically no rain, deserts will occur. In connection with the amount of moisture of a district, the prevailing wind should be considered. Winds that come over an ocean are more laden with moisture than those which have swept a continent. The physical nature of the soil, whether porous or not, modifies the effect of rainfall, and consequently the amount of the water-supply of the plant. Limestones—such as chalk—sand, and gravel, are very porous, and do not retain much water. The vegetation of such a soil as sand is far more limited than that of clay, which does hold water, for it is only plants which can protect themselves from too rapid transpiration that will be able to adapt themselves to a very porous soil. The presence of humus (Lat. *humus*, soil), or decaying vegetable matter, is essential to the production of good soil, and has several important functions. It increases the amount of water which sandy soils can retain, it tends to preserve the porous nature of stiff clays, and altogether to promote the friable condition of the soil.

The intensity and duration of light varies with the latitude. Observation seems to show that plants are even more affected by the duration of light than by its intensity. Tropical plants are exposed to a more regular succession of equal periods of light and darkness than temperate or arctic plants. On the other hand, in arctic regions plants, although they have light for a shorter period of the year, have it more continuously. It is stated that in Finland barley ripens in eighty-nine days, whilst a little further south it takes a hundred days, although the rays of light are stronger; but in Finland the days are longer, and the barley is therefore exposed to longer light per day, and this duration of light more than counterbalances the difference in the strength of the light.

Response of Plants to their Surroundings.

There is a constant struggle for life going on among plants as among animals. Unless a plant can adapt itself to the external conditions around it, which are constantly varying owing to the action of man and the forces of Nature, it must die. It is well known, for instance, that plants which live entirely submerged in water cannot live out of water; they cannot adapt themselves to atmospheric conditions, and therefore die. It is found that the vegetative organs of a plant, especially the leaf, are those that have this power of adaptability, whilst the flower is hardly at all affected. This is the reason that plants belonging to very different Natural Orders will be found associated together in the same district, and will tend to resemble each other as far as the root, stem, or leaf is concerned, whilst the structure of the flower is widely different. This power of adaptability is well seen in plants that grow by the sea. The leaves of the same species growing inland will be far less thick and succulent than those of plants growing by the sea. This may easily be observed in Lady's-fingers (*Anthyllis vulneraria*), Scurvy-grass (*Cochlearia officinalis*), and many others. It is interesting to note, too, that plants may attain the same purpose by different methods. Plants that grow on dry, rocky soils have to protect themselves against too rapid transpiration, and they may do this in a variety of ways—by developing a thick covering of hairs, or a layer of wax, or a very thick skin. In the next chapter the response of the plant to its surroundings, as far as its external form is concerned, is discussed, whilst Part II. treats of the adaptability of the plant to its environment in the minute structure of its vegetative organs.

Not only is there a constant struggle for life going on among plants owing to the variability of external conditions, but far more to the competition amongst themselves. That this must be so is evident when the number of the offspring of a single plant is considered. The number of seedlings produced by a single sycamore or an oak in its lifetime is immense; it can hardly be less than millions when the length of life of these trees is taken into account; but most of these seedlings will die, even if left alone by man, owing to the want of light and food, due to the want of space. No plant can increase in numbers unless it can find a suitable place for its seeds to grow in, or unless it can overcome weaker plants. In this severe competition, it is the plant which shows itself most capable of adaptability to its surroundings that survives. This brings us to the study of the plants that grow together, forming Plant Associations, in some respects the most interesting part of Ecology.

Plant Associations. A mountain, a moor, a valley, a wood, a marsh, even a hedgerow or a stone wall, each has its characteristic vegetation, which may differ from that of the adjacent moor or valley, etc. In some districts it is easy to see that one species dominates all others: thus gorse is the characteristic species of many commons; in other places heather is apparently struggling with gorse, and where there is a deficiency of peat will probably be conquered. Again, in some forests the beech is the prevalent tree, in others the oak, whilst in some cases a struggle is going on between the two. Warming states that in Denmark the oak has been replaced by the beech, but in West Jutland it is able to hold its own against the beech. Side by side with these "dominant" species, as they are called, there exist other species occupying a subordinate place, and therefore named "secondary"; these may be gradually replacing the dominant forms. Lastly, there may be in any given area plants which depend for their existence on the presence of the dominant species. A good instance of this is the undergrowth of a beech wood, which for the most part is dependent on the decaying vegetable matter of the beech leaves. The plants constituting the undergrowth of a beech wood in many cases would not be found in a pine wood, where there would not be enough humus for them.

Ecology investigates this relation of plants towards each other; it tries to explain how it is that certain plants are successful in the struggle for existence, it may be owing to more rapid growth, quicker germination, or longer duration. It shows which plants are social in habit, growing together in groups, as firs, wood anemones, grasses; which are sparsely intermixed, and which are solitary.

In Chapters IV. and V. these Plant Associations are discussed and suggestions made for field work.

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CHAPTER II

ECOLOGICAL CLASSIFICATION OF PLANTS

Flowering Plants classified according to Habitat.

FROM the point of view of ecology, Flowering Plants may be arranged in three well-marked groups :

I. Hydrophytes (Gk. *hydor*, water, and *phyton*, a plant), or Water-Plants. All plants which live entirely in water, or in soil containing 80 per cent. water, are by Warming included in this group.

II. Xerophytes (Gk. *Xeros*, dry, and *phyton*, a plant). These plants grow either on rocks, or in a soil which through the greater part of the year is poor in water, never having more than 10 per cent. The British Xerophytes are chiefly alpine or seashore plants (Halophytes, Gk. *hals*, salt). The conditions under which these two groups of plants grow are practically similar; the dryness of the mountain air and the salt of the sea air have the effect of increasing transpiration, whilst the salt in the soil tends to lessen absorption. These plants have to protect themselves from too great transpiration.

III. Mesophytes (Gk. *mesos*, middle). These occupy an intermediate position, and include all plants that are neither hydrophytic nor xerophytic. They like a good regular or seasonal rainfall, and a soil more or less rich in humus. By far the larger number of British plants belong to this group; they include not only the herbs of our hedgerows, meadows, woods, and moors, but also the majority of our shrubs and trees.

Characteristics of Hydrophytes.

Water-Plants include those that live entirely submerged in water and those that may be described as amphibious, living partly in and partly out of the water. The conditions of life lived under water are peculiarly favourable to growth and multiplication. To begin with, they are far more uniform than those to which a land-plant is exposed; there are not the sudden changes of temperature, which sometimes affect a land-plant so disastrously, because water gets hot less quickly and loses its heat less quickly than land. The processes of nutrition are also more easily carried on, for water contains more carbon dioxide in proportion than air, and an increase of carbon dioxide up to a certain limit makes assimilation more easy. Further, the whole surface of a water-plant is able to absorb water and substances dissolved in the water; this explains the fact that water-plants often have not roots, and when present they serve rather as organs of attachment than of absorption. The ease with which nutrition is accomplished leads to rapid development and growth, and this results in extensive vegetative reproduction; any portion of a water-plant that is broken off can exist independently, as it is not dependent on the production of roots for its food-supply. This is well seen in the case of the American water-weed, *Elodea canadiensis*, which has spread in the course of sixty years through western Europe, entirely by means of the breaking off of twigs, that have grown into new plants. In temperate regions, water-plants form special winter buds at the ends of their stems to protect themselves against frost; these drop off and fall to the bottom of the pond, where they remain during the winter, then the following spring they come up and expand into vegetative shoots.

The stems of water-plants have long internodes, and by the reduction, or almost entire absence of woody tissue, are very pliable, so that they are easily swayed by the current of water without breaking.

The leaves of water-plants vary very much. Those that live in swamps or marshes, or along the banks of a river where the water is either stagnant or moving very slowly, have narrow elongated leaves—*e.g.*, Iris, Loosestrife, Water Plantain, Bulrush. Leaves of this description are not so easily submerged, therefore the plant is not affected by floods. The leaves of plants which live entirely under water are often very finely divided, thus offering a greater surface for the absorption of the gases dissolved in water, whilst many plants which are only partly submerged have two sets of leaves, those floating on the surface not being cut up as those under the water are. Submerged water-plants do not transpire, therefore they have no cuticle and no stomata (p. 77); in the case of leaves floating on the surface of the water the stomata are on the upper surface. Kerner gives 11,500,000 of stomata for the leaf of a water-lily of ordinary size. In order that the stomata may not get filled with water and choked up, the surface of the leaf is such that water runs off easily.

It may here be mentioned that the tissues of water-plants abound in air cavities, which not only help in respiration, but give lightness to the plant, enabling it to float (see p. 63).

Submerged water-plants flower very seldom, and when they do are either especially adapted for water-pollination, or their flowers may rise above the surface of the water, and in that case they may be wind-, or insect-pollinated.

Characteristics of Xerophytes.

Xerophytes grow in dry situations—as, for instance, in the steppes of Asiatic Russia and the pampas of South America, where there is a long dry season; in arctic and high mountain regions, in sandy and rocky soils, and on seashores. In all these situations it is difficult at times for the plant to absorb as much water as it requires; the first requisite, therefore, is that the plant should protect itself from too great transpiration, and thus adapt itself to a lessened supply of water. The leaves of Xerophytes are everywhere characteristic of the group; they often have a very thick skin, as in the holly, or they may be covered with hairs to such an extent that the green colour of the leaf is concealed. Professor Henslow, describing the plants of the desert near Cairo, notes the greyness in colour, and attributes it to the intense hairiness. Sometimes, instead of hairs, a layer of wax is produced. Transpiration may also be reduced by a lessening of the number of the stomata, which may in addition be sunk in the leaf instead of being on the surface, and further, the leaf may be rolled in so that the stomata are doubly protected, for they are on the side of the leaf which is inrolled (p. 74).

In all these ways transpiration is lessened, but the means of protection just described against too rapid transpiration may be insufficient. Some xerophytic plants have adapted themselves to the dryness of the situation by a reduction of their leaves, in order to lessen the transpiring surface. This is very noticeable in seashore plants ; thus Saltwort (*Salsola*) has narrow, succulent leaves ending in thorns. Some seashore plants have practically no leaves at all—*e.g.*, Glasswort (*Salicornia*). Plants in which the transpiring surface is very much reduced have to make up for the assimilating surface lost by the reduction of the leaf. In some cases, as in the evergreen Butcher's Broom, the true leaves are reduced to mere scales, whilst short lateral branches, very much resembling leaves, are produced. These present their edge to the light, and transpire less than a leaf of the same size with its full surface exposed to the sun would do. Some Xerophytes, in which the leaves are very much reduced or absent, as in Glasswort, have special assimilating tissue in the stem (p. 62). As a provision against the irregular supply of water many Xerophytes have a water-storage tissue, which accounts for the succulency of the leaf.

In connection with the irregular supply of water, it should be noted that xerophytic plants usually have long tap-roots, or long underground stems. The surface of the soil is the part most affected by extremes of temperature, or dryness of the atmosphere, so that the longer the root is, the more likely it is to come in contact with water, which may exist some depth below the surface. Probably it is the presence of water at some depth below the surface that leads to the growth in length of the root, for roots, especially at their tips, are peculiarly sensitive to the presence of moisture.

The thorniness of Xerophytes is very striking, and is probably a means of protection against grazing animals. In Cactus, for instance, the leaves are reduced to spines.

The buds of Xerophytes are protected against extreme heat by being deeply sunk among the leaves, or they may be situated in a groove in the stem. The stamens are usually conspicuous, as there is no fear of the pollen being washed away by the rain. The seeds, which need to be protected from severe droughts, are enclosed in hard, woody fruits, which in many cases open out only in the damp to let out the seeds.

In the tropics many Epiphytes—*i.e.*, plants which grow upon others without obtaining their nourishment from them—are xerophytic, as, for instance, many orchids with aerial roots. The Epiphytes in Britain are not as a rule Flowering Plants, but belong to lower groups, such as Mosses, Lichens, etc.

Characteristics of Mesophytes.

Mesophytes are a very large group of plants. They include the thousands of common herbs found in meadow and pasture, on moor and hill, the shrubs of our hedgerows, the trees of wood and forest. They offer every variety of habit: some are creeping, others climbing; some love shade, others require much light, but all agree in demanding a fair supply of water. Mesophytes are not sharply marked off from Xerophytes on the one hand, or from Hydrophytes on the other; there is no possibility of confusing a Xerophyte and a Hydrophyte, but there is a gradual transition between the Mesophytes and these other groups: they merge into each other.

Speaking broadly, Mesophytes differ from Xerophytes in their regular and constant transpiration, hence the structure of the leaf is different. In the Mesophyte the lamina is usually thin, expanded at right angles to the direction of light; stomata abound on the lower surface, and sometimes occur also on the upper—in short, there is every facility for transpiration. The chief advantage of thorough transpiration is that it accelerates the distribution of water and dissolved food substances through the plant. Food substances, it must be remembered, can enter only in dilute solutions, so that a great deal of water has to be absorbed in order that the plant may get sufficient food, consequently the plant must be able to get rid of water.

Mesophytes differ from Hydrophytes in having a well-developed wood system for the conduction of water and food material, as well as for other purposes. In Water-Plants there is no current of water through the plant as in Mesophytes, for plants living in water imbibe their nourishment along their whole surface, and it passes from cell to cell by a process of diffusion; in Mesophytes a conducting tissue, such as wood, is necessary for the conduction of water and substances dissolved in it.

The root, stem and leaf of Mesophytes show a considerable variety of structure according to the habitat of the plant. These will be fully discussed in Part II.; here the following groups, which have peculiarities in their mode of life, and which occur in varying habitats, are considered—namely, (*a*) Climbing Plants; (*b*) Insectivorous Plants; (*c*) Parasitic and Saprophytic Plants.

(*a*) **Climbing Plants.** Climbing Plants are subdivided by Darwin into: (i.) Twining Plants; (ii.) Climbers with sensitive organs; (iii.) Hook Climbers; (iv.) Root Climbers. Honeysuckle, and Woody Nightshade, may be taken as instances of woody plants which climb by means of entwining their stems over bushes and trees to a considerable extent; their stems increase in thickness from year to year. Hop, Convolvulus, Black Bryony, also climb by means of twining stems, but these come up fresh each year from the rhizome; the Scarlet-Runner is an example of an annual with a twining stem. The tip of the stem in twining may describe quite a large circle, and thus has a good chance of finding support. The spiral may be in the direction of the hands of a clock, or in the opposite direction; usually the same species twines the same way throughout. The Nasturtium and Clematis are instances of plants that climb by twining petioles.

Climbers with sensitive organs for the most part develop tendrils, which may be stems, leaves, or parts of leaves.

Stems modified into tendrils occur in the Virginian Creeper and in the Grape-vine. The tendrils, by means of which the Passion-flower climbs, are also modified branches.

Leaflets modified into tendrils occur in many of the Leguminosæ, especially Vetches.

Aerial roots modified into tendrils occur in the Vanilla.

The two British hook-climbers are the Blackberry (*Rubus*) and the Goose-grass (*Galium*). The hooks with which they are furnished are outgrowths of the outer skin, and materially help the plant in catching hold of the shrub or bush. This may be easily seen if one tries to separate a blackberry stem from the hedge on which it is twining.

The best known root-climber in England is the Ivy, the roots of which penetrate so far into the crevices of walls as even to cause them to crumble away in course of time. In the tropics, some species of Ficus grow round trees by means of their roots, clasping them in a close embrace which may injure and even kill them.

It is interesting to inquire of what advantage it is to a plant to be able to climb. It is, no doubt, by means of their power of climbing that many plants secure enough light for their development. Supposing that a bramble could not make its way to the top of a hedge, or of the shrub with which it came in contact, it would not be likely to get enough light for the perfection of its fruit. In the tropics to be able to climb so as to reach the light is a very important matter, for there trees are mostly evergreens, and many plants, unless they had the power of climbing, would be condemned to live in perpetual shade; in England, on the other hand, many herbs inhabiting woods flower before the leaves come out, and thus get enough light and warmth to bring their fruit to perfection. Kerner suggests that tendril-bearing stems have an advantage over twining stems. They reach the same height above the ground, he thinks, with less expenditure of material; the twining stem of the Scarlet-Runner when it has climbed a metre measures 1½ metres, whereas a Pea at the same height above the ground measures only a metre.

(*b*) Insectivorous Plants. Insectivorous plants usually grow in soils poor in nitrogen; they therefore get their extra nitrogen from the dead bodies of the insects they capture by means

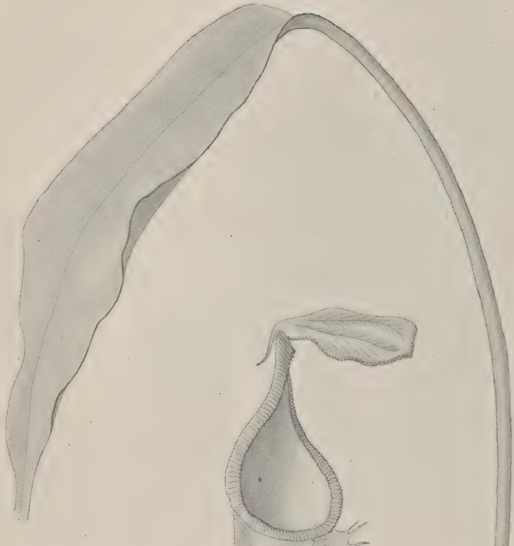

PLATE I.

Pitcher of Nepenthes.

of special apparatus generally developed in connection with the leaf. These plants may be divided into two groups according to the nature of the apparatus.

1. Those that catch insects by means of traps—*e.g.*, Pitcher plant, Bladderwort.

2. Those that perform movements in the capture of their prey—Sundew, Butterwort. In each case the means of attracting the insect, its capture, and the arrangements for digestion, must be considered.

In the Pitcher-plant (*Nepenthes*), which belongs to tropical regions, but may be seen in English greenhouses, the petiole is modified into three parts—a leaflike branch or phyllode, a tendril, and a pitcher (Plate I.). The lamina of the leaf forms the lid of the pitcher, the whole apparatus being a regular trap, into which the insect is enticed. It is attracted by the brightly coloured streaks on the lid and by the honey on the under side of the lid and round the mouth of the pitcher. It is captured by bristles round the rim of the pitcher; these bristles point inwards, so that the insect cannot escape backwards, and as the inside of the pitcher is slippery, it loses its foothold, falls into the liquid at the bottom, and is quickly drowned. As soon as the insect reaches the bottom of the pitcher, more liquid is secreted; this contains an acid, by which the body of the insect is digested; the cells lining the pitcher absorb the products of digestion. The function of the tendril is to enable the Pitcher-plant to grasp other plants, which may be more conveniently situated for the capture of insects.

Bladderwort (*Utricularia*) is abundant in little pools of still water in peat-bogs. Here the trap takes the form of a bladder developed instead of leaves on some of the threadlike stems. Each bladder has a valve which opens inwards (Plate II., Fig. 2). An insect pressing against it pushes it in, but as soon as the insect has entered the bladder and is no longer pressing against the valve, the elasticity of the valve makes it spring back and close the opening. The insect then cannot escape. What attracts the insect to the bladder is not known;

Kerner suggests that it may expect to find food, or it may be seeking shelter from other insects. The fact that only very small insects can enter the bladder seems to indicate that they are in search of refuge from larger insects. The bladder is lined with cells especially adapted for absorbing the products of the decaying body; there does not appear to be any special digestive juice as in the Pitcher-plant.

Sundew and Butterwort are abundant in boggy patches of moorland. Both catch animals by movements of their leaves. In the Sundew (Plate II., Fig. 3) the leaves are covered with delicate red filaments, largest at the edges; there are about 200 on a single leaf. Each filament bears at its extremity a gland, which secretes a sticky juice that the insect mistakes for honey. As an insect alights on the leaf the tentacles bend inwards, the tentacle that is first irritated being the one to move first; then movement is set up in the whole fringe of tentacles, and the insect cannot escape. The secretion of juice by the tentacles is increased as soon as the insect touches them; the juice is acid, and by means of it the nitrogenous substances present in the insect's body are digested. If an insect is caught by a marginal tentacle, it is gradually transported towards the middle of the leaf, where the digestive fluid is poured out in greatest quantity. Digestion takes at least a couple of days; the tentacles remain bent during this period, and the leaf more or less curled up. When digestion is complete, the tentacles straighten themselves, and the leaf unfolds.

Butterwort is very abundant on damp moors; its radical leaves form a rosette, and are pressed back against the surface of the ground; being of a yellowish green, they are very conspicuous (Plate II., Fig. 4). The margins of the leaf are slightly upturned, forming a kind of trough, and the whole surface is covered with glands secreting a sticky fluid. It is said that a plant bearing six to nine leaves will have about half a million of these glands. An insect alighting on the leaf stimulates it, causing the edges to curl over, and the sticky fluid prevents the insect's escape. The presence of the

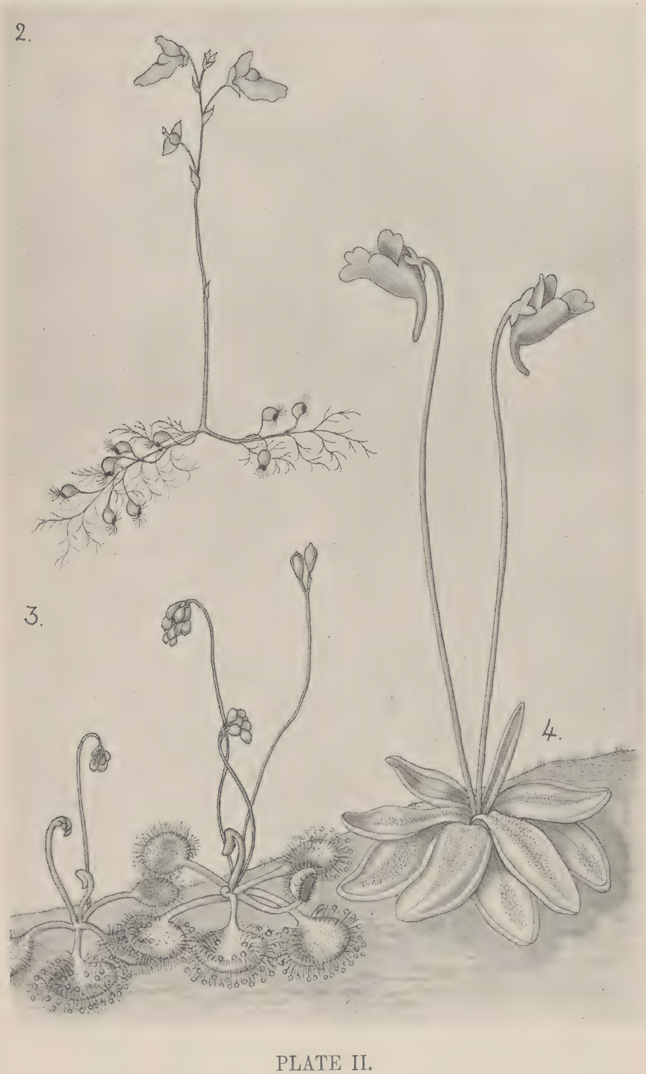

PLATE II.

Fig. 2.—Bladderwort.
Fig. 3.—Sundew.
Fig. 4.—Butterwort.

insect stimulates the glands, which after a few hours pour out a distinctly acid juice, by means of which the insect is digested.

(*c*) **Parasitic and Saprophytic Plants.**

Some plants are total parasites, getting their food from other plants, which are called their "hosts"; these have little or no chlorophyll—*e.g.*, Toothwort, Broomrape, Dodder. Other parasitic plants are only partly so; they get some of their food from the plant on which they live, but they also get a good deal—perhaps the greater part—just as an ordinary green plant does. These semi-parasitic plants may again be subdivided into—

1. Those with roots of their own and leaves, *e.g.*—Eyebright, Bartsia.
2. Those that have green leaves, but no true roots—*e.g.*, Mistletoe.

Toothwort (*Lathrœa squamaria*) is parasitic on the roots of trees, such as ash, poplar, hornbeam, hazel, in fact on almost any angiospermous tree. It lives entirely underground except for a short period, when it sends up a few flower-bearing shoots. It has no roots of its own, but attaches itself by suckers to the roots of the tree on which it is living. Certain cells in the sucker are especially adapted for the absorption of nourishment from the root. The subterranean stems are white, and are covered throughout their entire length with thick, scaly leaves similar in colour to the stem. It is stated that these leaves are also insectivorous, forming traps somewhat similar to those of the Bladderworts. In the spring, inflorescences arise from the extremities of the subterranean scaly shoots. They are purplish in colour and at first crook-like, but they straighten themselves by the time the fruit is formed so that it may ripen thoroughly.

The union of the Broomrape (*Orobanche*) with its host is so close that it is difficult to say where the one ends and the other begins. The Broomrapes are very select in the choice of their hosts: thus one species lives exclusively on Wormwood, another on Butterbur, a third on the Wood Sage, etc.

The seeds of Dodder germinate late in the spring, independently of the host plant, on damp earth, on putrefying matter. The embryo, when it has emerged from the seed-coat and used up all the endosperm, is a delicate thread, capable of standing erect for a time and curving round so that it may come in contact with some suitable support. If it does not come in contact with some support, it may lie on the ground, even for four or five weeks, waiting for something. When it does become attached to a stem or some part of a living plant, it develops suckers, by means of which it fastens itself to its host, and then the part of the Dodder which was in contact with the ground dies off. This gives the plant the appearance of having germinated on the host plant. The host on which some species of Dodder thrive well is the Hop or Nettle; it develops on these plants a number of suckers and tendrils, forming a regular network. Rose-coloured flowers are formed on filaments of this network, and from them balls of capsular fruits, which dehisce by means of a lid and have their seeds shaken out by the wind. The Greater Dodder is parasitic on a great variety of herbaceous plants; the Lesser Dodder on Thyme, Heaths, and other small shrubby plants.

The semi-parasitic plants belonging to the Scrophulariaceæ are discussed in connection with that Order (p. 127 and Figs. 114-116); here it will be sufficient to give the Mistletoe. This is parasitic upon trees; the Black Poplar is said to be its favourite. The berries are disseminated by birds, especially thrushes, which thrive upon them; the seeds become attached to the bark of trees. When the seed germinates, the radicle of the embryo develops into a regular attachment disc, from which a process penetrates through the bark as far as the wood. This process is called a "sinker"; it always penetrates straight in, whatever the direction in which the seed reaches the branch, so that the Mistletoe may come off on any side of a branch. By the end of the winter the tip of the sinker has just reached the wood. The following spring, when fresh wood cells are added to the branch, the sinker becomes enclosed on each side by them; at the same time, by means of a layer of cells at its base, it grows in length exactly as much as will equal the thickness of the new layer of wood: for this reason it never becomes closed by the annual rings of wood. On making sections of the wood, the sinkers are easily seen. Whilst the sinkers are thus spreading in the interior of the branch, the stem of the Mistletoe develops outside the host; then follows the formation of the leaves, flowers, and berries. It is reckoned by examination of the rings of wood and sinkers that a Mistletoe may live forty years.

Saprophytic Plants. These plants live on decaying matter (Gk. *sapros*, rotten), either vegetable or animal. The majority belong to one of the lowest groups of plants—the Fungi. The best known example of a Flowering Plant is the Bird's Nest Orchid, which lives on the humus of beech leaves.

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CHAPTER III

DISTRIBUTION OF PLANTS

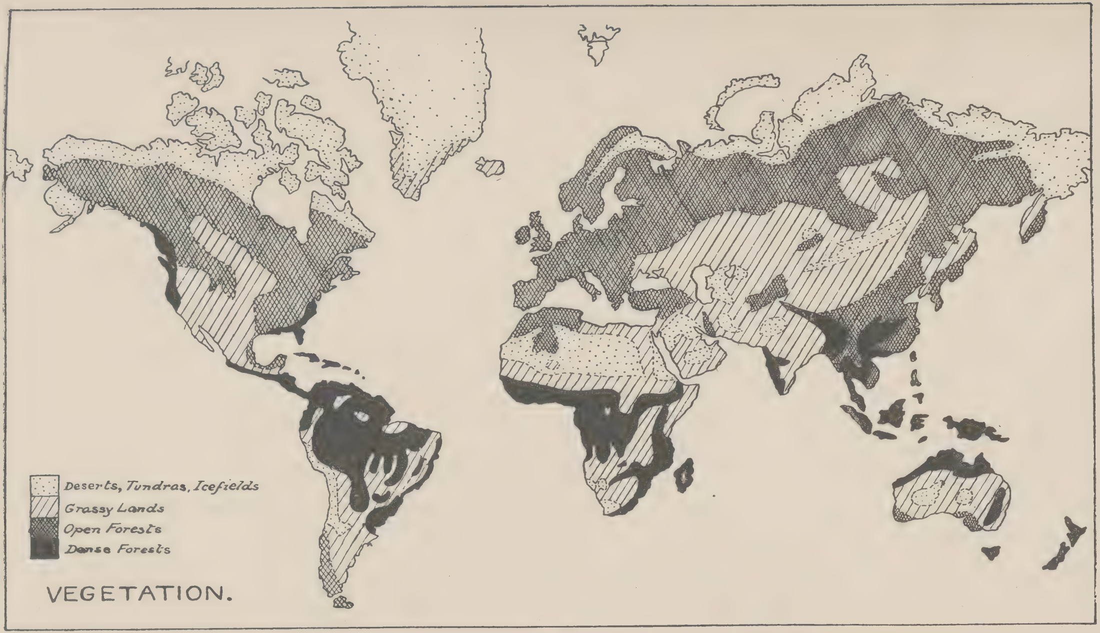
It is impossible thoroughly to understand the vegetation of any country without some knowledge of the following important facts, which largely determine it:

1. The position of the country in question with regard to the chief climatic zones of the world;
2. The climatic changes that have taken place in past geological ages;
3. The changes in the geographical distribution of land and water;
4. The influence of man.

The influence of the above factors on the present distribution of plants in Great Britain will now be considered.

Climatic Zones. It will be seen from the accompanying table, which gives a bird's-eye view of the three main climatic zones of the present day with their accompanying vegetation and its ecological characteristics, that the vegetation of Great Britain must be largely mesophytic.

Climatic Zone.	*Amount of Rainfall.*	*Vegetation.*	*Character of Vegetation.*
1. **Tropical.**	Heavy	Dense forests of Evergreens	Mesophytic
	Deficient	Desert plants	Xerophytic
2. **Temperate.**	Poor	Desert plants	Xerophytic
	Fair and seasonal	Grass lands	Xerophytic
(Great Britain)	Good	Open forests of Deciduous trees and Conifers	Mesophytic
3. **Arctic.**	Poor	Mosses, lichens, saxifrages	Xerophytic



MAP, ILLUSTRATING DISTRIBUTION OF VEGETATION.

It must be remembered that in each of the regions given in the above table, where only latitude is considered, the vegetation will vary with the altitude. The three climatic zones are present in each region, provided a certain height above the sea-level is reached. Thus in the tropics, the plants characteristic of temperate and arctic regions will be met with at certain elevations; similarly, arctic plants are found in the temperate zones.

Climatic Changes in Geologic Ages.

The fact that alpine and arctic species are found in tropical and temperate regions can be explained only by a reference to past geological changes. Geologists speak of Primary, Secondary, Tertiary Ages, and they tell us that Flowering Plants are known to belong to the Tertiary period, whilst non-flowering plants, such as Algæ and Ferns, are much older, and have been found in the oldest, or Primary, rocks. It is possible that, as fossiliferous rocks all the world over are more and more examined, Flowering Plants will be found to be older than is at present believed. During the Tertiary period there were great climatic changes on the earth's surface. At the beginning of the period the climate seems to have been very much warmer than at the present time, so that what we now call the polar regions had plants similar to those found to-day in sub-tropical countries. Then the climate gradually grew colder, and new species adapted to the new conditions appeared in the north, and extended southwards, giving rise, it is thought, to the flora of the temperate regions of the present time. The climate went on getting colder, and in time arctic species appeared. Then came the Glacial Epoch, when tropical plants were driven south to the torrid zone, and arctic species reached as far south as the Pyrenees. Then, as the cold of the glacial period lessened, those arctic species which had migrated southwards remained on the mountain ranges, hence the presence of arctic plants on the tropical mountains of the world. A similar glacial period in the southern hemisphere would account for the appearance of alpine plants in the southern continents.

The following table shows the chief subdivisions of the

Tertiary Period, and the probable climatic conditions, with representative vegetation. This table is only intended to be suggestive. As fossil botany is more thoroughly and systematically studied it is probable that new light will be thrown on this subject. The oldest rocks are given at the bottom of the table, and recent rocks—that is, those later than the Tertiary Period—are omitted: they belong to what is called the Post-Tertiary Age.

TABLE OF TERTIARY PERIOD.

Rock.	*Climatic Conditions.*	*Vegetation.*
Pleistocene (latest)	Cold, marked by milder intervals	Temperate plants
	Glacial Epoch	Arctic plants migrate south
Pliocene	Temperate, gradually getting colder	Arctic plants appear towards end of period
Miocene	Unrepresented	No fossil plants of this period to be found in Britain
Oligocene	Colder than Eocene	Temperate plants
Eocene (oldest)	Much warmer than at the present time	Oldest known flowering plants

Changes in Geographical Distribution of Land and Water.

The effect of changes in the geographical distribution of land and water on the existing distribution of plants is well seen in the case of oceanic and continental islands. Those islands which are close to, and at one time probably formed part of, the adjoining continent will have much the same flora as that of the continent to which they belong geologically. In oceanic islands this would not be the case; their flora would be very different, and would have many species peculiar to themselves. Such forms are said to be endemic.

Great Britain and Ireland are continental islands; the flora is therefore, on the whole, continental, derived from the continent of Europe, and for that reason has few, if any, endemic forms. But, as our islands have a very changeable climate, only those continental species which are best adapted for holding their own in a variable climate are found.

Influence of Man. The forms of life in a country or district are nowhere stationary. At the present time, as in the past, there are migrations of plants, the disappearance of some species, the gradual development of others; but these changes take place so slowly, if Nature is left to herself, that they are almost unnoticed. For centuries, however, the distribution of life, both animal and vegetable, has been considerably modified by the action of man. Animals are introduced into an island and the flora changes, as has been the case in St. Helena owing to the introduction of goats. Or certain wild animals are exterminated, and this leads to the rapid increase of certain others—*e.g.*, field-mice—which had formerly been kept down, and they in their turn may destroy so much vegetation as materially to affect the district. It has been shown, for instance, that the abundance of red clover in a district will depend on a good supply of cats—and that certainly depends on man—to kill the mice which would otherwise destroy and keep down the humble-bees, and thus prevent the pollinating of the clover. The action of man in clearing forests, in draining swamps, in cultivating waste ground, in fact in all the operations of agriculture, has an enormous influence on the vegetation of a country. The clearing of forests means the lessening the amount of rain, and as the majority of plants need a regular rainfall, this often becomes a serious matter; the effect of draining is disastrous to marsh-loving plants, as may be seen in Cambridgeshire, for, with the exception of Wicken Fen, the Fen District may be said to have disappeared.

British Floras. The chief British Floras as given in Reid's "Origin of the British Flora" are:

(1) A *Lowland Flora*, similar to the temperate flora of the neighbouring lowlands of Belgium and France.

(2) An *Upland Flora*, consisting of more or less isolated portions of the flora of the arctic regions and the Scandinavian mountains. This flora is confined to hills high enough to have

an average temperature approaching that at the sea-level in the arctic circle.

(3) A *sub-arctic flora* is found over a great part of Scotland and on isolated hills in Britain.

These represent the continental flora, if it may be thus expressed, of Britain.

Besides the above, there are two very specialized floras—namely, the aquatic flora of the eastern counties and the flora of Devon, Cornwall, and West Ireland, in which plants characteristic of the Pyrenean region are found. This last is known as the Lusitanian flora.

There are several theories as to the way in which plants of the Pyrenean region could have reached West Ireland: from the fact that these plants have for the most part minute seeds, it has been suggested that migrating birds carried the seeds across. If, as is now generally thought, the western coast-line of Europe was far more extended than it is at present, and that land which is now submerged was once above water, it is very probable that the plants were able in those past ages to migrate overland, and have remained in Devon, Cornwall, and Ireland, owing to the milder climate.

It will be clear from what has been said in this chapter how necessary the study of geology is for a right understanding of the origin of floras.

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CHAPTER IV

PLANT ASSOCIATIONS

ANYONE who has observed plants at all carefully must have noticed that certain plants grow together; those found in hedgerows are different from meadow plants, those on exposed moors from the sheltered valley flora.

Those plants which grow together under uniform conditions of soil and climate form a Plant Association; for instance, river plants, those growing above a certain height, those of a beech-wood, or those of a bog, constitute in each case an association; they are related to each other ecologically, although they may belong to quite different Orders. As a rule, such plants will resemble each other in the structure of their stem or leaf, in their vegetative organs generally, however widely different the flowers may be.

In a Plant Association it is usual to distinguish between—

(*a*) The plants which predominate in the given area—*e.g.*, Heather, Oak, Grasses;

(*b*) The subordinate forms which may be struggling for dominance—*e.g.*, Bilberry with Cotton-grass;

(*c*) The plants dependent on the dominant forms.

A Plant Association will include a larger or smaller number of forms, according to the dominant form selected. Thus, supposing the vegetation of a heather moor is being described, the plants found in the area in which the heather is predominant will be more numerous than one in which the cotton-grass is the dominant form selected. Or, supposing the beech is selected as the dominant form, then the association will be smaller than if the oak were the chief form of the area fixed on for investigation.

As yet comparatively little systematic work of this kind has been done in England, so that it is difficult to get sufficient observations from which to generalize. The following Plant Associations are those which have so far been most fully described:

1. Mountain or Alpine vegetation.
2. Moorland, including bogs.
3. Woodland, as that of Pine, Birch, Oak, Beech.
4. Pasture vegetation.
5. Meadow ,,
6. Aquatic ,,
7. Hedgerow ,,

Alpine Vegetation. Alpine plants are found only at great altitudes, or on the sea-coast. Ben Lawers, the third highest mountain of the British Isles, is one of the richest in alpine plants, whilst in West Ireland many of the plants found on the mountains and high moors in other parts of the British Isles grow right down to the sea-level. Thus the level varies in different parts of Britain and Ireland, as would be expected from what has already been said in Chapter I.

Alpine plants are generally small and compact, able to defy winter frosts and summer droughts. They are perennials, for, owing to the winters being long and the summers short, they would have no time to ripen their fruit if they had to grow from the seed each year; but being perennial, they prepare during the winter for the growth of the next summer, and as the flowers are borne on short stems, which do not take long to grow, the plant is ready to flower almost as the summer comes.

The brilliant colours of alpine plants are hardly realized in England, but in Switzerland this is evident to the most casual observer; the blue of the gentians, the red saxifrages, the bright pink of some of the campions, the reddish-purple of the willow-herbs, are instances that may be quoted. Even in Britain there are a few conspicuous examples of brilliant flowers among small mountain plants, as Moss Campion (*Silene acaulis*), White Dryas, etc. It is suggested that the brilliant colouring of alpine plants is due to the brighter light and to the fact that the period of cross-pollination is so short that without brilliant colouring insects might not be attracted.

Alpine plants are xerophytic in character; the leaves are often covered with hairs, giving them the silvery white colour so well known in the Edelweiss. It is interesting to compare alpine species with the corresponding lowland form; thus the alpine species of Lady's Mantle (*Alchemilla alpina*) has this dense covering of hairs, which is absent from the common lowland form, *Alchemilla vulgaris.*

Moorland Vegetation. Moors vary not only as regards soil, but, above all, in the amount of water present in the soil. On these two factors it largely depends what dominant forms are present. The moorland of the West Riding of Yorkshire has been thus arranged by Dr. William G. Smith and Mr. C. E. Moss:

(*a*) Cotton-grass moor, called "moss moor," from the fact that the bog-moss Sphagnum usually forms (although it is not so conspicuous in Yorkshire) an important constituent of the peat. This "moss moor" is practically a bog.

(*b*) Heath moor.

(*c*) Rough-grass moor.

In Yorkshire the cotton-grass moors extend for miles; they require a permanently wet soil, with a rainfall of at least 40 inches. The flowering plants are very few. The Bilberry (*Vaccinium*) and a few heaths are the most abundant. Bog-asphodel and Sundews are rare. It is interesting to notice the struggle that is going on between the Bilberry and the Cotton-grass; where the moor is wind-swept and drier the Bilberry ousts the Cotton-grass, and becomes the dominant form. It should be noted that heather is scarce in a cotton-grass moor.

The Heath or Heather moor is far drier, and requires a better drainage than the moss moor. It occurs on the edges of the latter, and in patches. The plants forming the Heather moor association are far more numerous than those of the Cotton-grass; furze and broom may be mentioned, also several sedges and grasses.

The Grass moor is dominated by grasses. This shows two well-marked divisions: there is the dry grass heath, where there is almost no peat and the chief grass is Molinia; and the wet grass heath with peaty soil, the dominant grass being Festuca. This latter has far more plants than the former. Grass heaths differ even within the limits of a county; those of North Yorkshire have more plants than those of the West Riding.

Woodland Vegetation. Pine forests are not nearly as extensive in Britain as they were centuries ago, or as they are even now in other parts of the northern hemisphere. North Canada, North Scandinavia are still covered by pine-woods, and in the Pyrenees and the Alps there is still a belt of pines above the oak. As compared with the oak or beech, the pine has more marked xerophytic conditions; the stomata are sunk below the surface of the leaf, and it is calculated that the pine only gives off about one-sixth of the amount of water transpired by an average oak in the same time. The fact that the leaves of pines do not decay rapidly and form humus quickly may account for the scantiness of the undergrowth.

The birch is often found associated with the pine. It can grow on many kinds of soil; for instance, in the clefts of rocks, on dry gravel or sand, and even on wet moors. It requires plenty of light, and as its crown is open, much light comes through, and the undergrowth is very varied and abundant. The birch may almost be considered a transition between Mesophytes and Xerophytes; on the whole it is xerophytic, but not as markedly so as the pine, and its undergrowth includes a far larger number of Mesophytes than does that of the pine.

The oak and beech are distinct Mesophytes; the former requires more light than the latter, and as its crown is less thick and shady than that of the beech, its undergrowth is far more varied and richer. The upland oak-wood may usually be distinguished from the lowland; the former is usually dry, rocky, deficient in humus, and characterized by an undergrowth of late-flowering Xerophytes; the latter is damp, shady, and richer in humus, its undergrowth is more abundant in species, particularly of the bulbous and early-flowering kinds. The undergrowth of the beech is limited for two reasons: (1) The beech can grow in situations with much less light than the oak, and as it has a very thick crown when its leaves are fully out, it lets through very little light; (2) its leaves decay slowly—not nearly as rapidly as those of the oak—therefore suitable soil is much more slowly formed. It follows that the undergrowth will consist mainly of two classes of plants: (*a*) Spring-flowering plants, which come out and blossom before the leaves of the beech are fully out; and (*b*) plants which live on decaying vegetable matter, and are therefore independent of light. The number of spring flowers found in a beech-wood depends on the closeness of the trees. Where they are crowded there is hardly anything to be found; where the wood has been thinned the ground will be thickly covered with early spring flowers, such as Dog's Mercury, Anemones, etc. In summer saprophytic plants—*e.g.*, Bird's-nest orchis—will be found in those beech-woods where the soil is rich in humus from the decaying leaves of several years (Appendix B).

Pasture Vegetation. In England, and probably in North Europe generally, what is now pasture land was originally woodland, and if left to themselves pastures would revert to woods and forests. The vegetation of pasture land is limited in variety, and depends largely on the animals that are turned out to graze; it is stated that the goat nibbles more closely than any other animal, and destroys every seedling that comes in its way. The herbs of a pasture are far less numerous than those of a meadow, especially in the case of a meadow given up to turf grass. A pasture is usually drier and higher than a meadow, and the smaller amount of moisture very much affects the character of the vegetation.

Meadow Vegetation. Meadows are usually low-lying, often containing a good deal of water, but the ground-water does not come so high as in a swamp or marsh, and the water flows more, so that a meadow is more or less drained, whilst a swamp has more or less stagnant, or at any rate slowly flowing, water. The vegetation of a moist meadow approaches Hydrophytes in character, and includes many plants which are social in habit, as grasses.

The following are the chief types of vegetation in meadows:

(i.) Grasses, some of which are especially cultivated for hay, whilst others form turf. The importance of grasses in a meadow can hardly be overrated; they break up stiff soils by their long roots, or they may help to keep the surface soil from being washed down by heavy rains; they modify the effects of radiation and evaporation.

(ii.) Herbaceous plants. These are almost always perennials. (Cathartic flax, *Linum catharticum*, is almost the only annual.) They often have creeping rhizomes; the leaves are thin, flat, and broad, admitting of regular transpiration. The wealth of flowering is striking, and accounts for the abundance of insect life, and that, in its turn, reacts on the vegetation; for by bringing about cross-pollination insects tend to insure the propagation of plants. In meadows cultivated for hay the vegetation is naturally affected by mowing, which prevents the ripening of seeds. Cornfields have not been discussed, because the conditions are artificial, owing to the planting of seed by man.

Aquatic Vegetation. This includes two well-marked groups of plants: (1) Those living almost entirely under water, in some cases even being pollinated under water—*e.g.*, Hornwort, Milfoil, Grass-wrack (*Zostera*), Elodea, Water-soldier, etc. (2) Those which are partly submerged and partly out of the water—*e.g.*, Yellow Water-lily, Frogbit, Pondweed, Water-plantain, etc. This is a far larger group than the preceding.

Hornwort (*Ceratophyllum*) and Milfoil (*Myriophyllum*) have floating stems and fine linear leaves which are in whorls. Hornwort is adapted for pollination under water, whilst Water Milfoil bears its flowers on a spike which protrudes out of the water. When Whorled Milfoil is growing in deep, clear waters it appears to be pollinated under water; but if growing in shallow, muddy ditches, the flowers may form a spike, as in the other species, the Water Milfoil. Both Hornwort and Milfoil have very much cut-up leaves—a feature common in water plants. Grass-wrack (*Zostera*) is an instance of an aquatic plant growing near the sandy edges of the sea, usually below low-water mark. The stem creeps and roots in the sand or mud, and it has long, grass-like, alternate leaves. Its flowers are adapted for pollination under water.

Elodea and Water-soldier (*Stratiotes*) are instances of aquatic plants which are pollinated out of the water. Elodea has already been described in some detail (p. 9). Water-soldier, like the Whorled Milfoil, has also a rootstock, creeping in the mud. This produces at the bottom of the water tufts of long narrow leaves bordered by small teeth. The flower-stalks rise a few inches above the water. This plant is common in the fens of eastern England.

Frogbit (*Hydrocharis*) is a plant commonly found in canals. It has a floating stem, with floating tufts of radical leaves and submerged roots; the leaves are about two inches across. The fruit ripens under water. It is thus partly submerged and partly out of the water; to this group belong also the Pondweeds (*Potamogeton*). These in many cases have two sets of leaves, some submerged, others floating on the surface. Duckweed (*Lemna*) is an aquatic plant, with stems floating on the surface, and generally called fronds, from the under surface of which are given off the roots (fibres) with distinct root-caps. This plant is found on the surface of ponds and still waters.

Marsh and river plants are rather different in character from those just described. The characteristics of plants growing by the banks of a river are that they are tall and narrow-leaved, whereas those which frequent marshes, and are beyond the reach of floods, often have large leaves, as, for instance, Docks, Butter-Bur, Wild Angelica. The plants by the banks of a river are chiefly Monocotyledons—*e.g.*, Bur-reed, Sweet Flag, Bulrushes, Reeds, Cotton-grass, Sedges, Water-plantain; where Dicotyledons occur they often have narrow lance-shaped leaves, as the Spearworts, p. 149.

Some of the more common marsh plants are the Red and

Yellow Rattle, Figwort, Meadowsweet, Marsh Marigolds, Water Violet, Bog Pimpernel, Marsh Valerian, Common Mallow. It depends to a certain extent on the nature of the marsh—for instance, whether it is a salt marsh or not—what the vegetation will be; thus Wild Celery, Slender Hare's ear, Sea Starwort, all belong to salt marshes.

Hedgerow Vegetation. The vegetation of hedgerows affords an instance of the influence of man on the flora of a locality. The shrub of which the hedge consists was originally planted there, and is generally kept trimmed, so that the conditions are not natural. In many parts of the country the shrub chosen is hawthorn, but it may be blackthorn, ash, holly, yew, and even elm. Where the hedges are carefully looked after, as near towns, there is very little undergrowth; but in country lanes the plants clothing the banks beneath the hedge are very numerous. As a rule, it will be found that the undergrowth differs considerably on the two sides of the lane, owing to the difference in the angle at which the light falls on the bank; on one side the plants will be protected by the hedge from the morning and midday sun, whilst the opposite side will be fully exposed to it. The following plants were found on the shady side of a country road on the Cotswolds in the third week of June: Germander Speedwell, Herb Robert, Hedge Garlick, Black Bryony, Red Campion, Buttercup (*Ranunculus acris*), Bedstraw, Stinging Nettle, Dog-rose; whilst on the opposite side it was only possible to find Mouse-ear Hawkweed, Thyme, a species of Geranium, and Common Bird's-foot Trefoil. This side was much drier and exposed to the sun.

Observations were made in another lane, a very sheltered one, not far from the one just mentioned, but lower down. Large trees almost met overhead, above the hedges, so that both sides of the lane were in shadow even at midday. Here the undergrowth was much greater, and there was little difference between the two sides of the road. The plants here were the following: Very fine Meadow Buttercup, Hogweed, Germander Speedwell, Hedge Parsley, Cleavers, Chickweed (*Cerastium vulgatum*), Geum, Red Campion, Cinquefoil, though not in flower, Herb Robert, Meadowsweet, and a large number of Grasses, all in the perfection of blossom.

It should be noticed how many climbing plants are found in hedges—Honeysuckle, Bindweed, Black Bryony, White Bryony, Clematis, Roses, Blackberry, etc. The mechanism by which plants climb has already been discussed (Chapter II.).

In some parts of the country, instead of hedges stone walls are built, and in the crevices between the stones a large number of plants will be found. In South Cornwall the number of plants found on stone walls is striking. Ferns abound, and the following not very common Flowering Plants may be mentioned: Valerianella, Subterranean Clover, Field Madder, Pennywort in abundance, Trigonella. These plants must be more or less xerophytic in character, as there is no great depth of soil for them. They are for the most part small, creeping, and very hairy.

In the next chapter some suggestions as to the practical work that should be done in order to map out the vegetation of a district on these lines is given.

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"Open-Air Studies in Botany": Lloyd Præger.

CHAPTER V

FIELD WORK ON ECOLOGY

THE following observations, most of which have been tested and found practicable, are suggested :

I. To ascertain the Vegetation of a district, say of a given moor or wood—

(*a*) The first thing is to ascertain what the dominant plant is—in the case of a wood, whether the prevailing tree is beech, oak, fir, etc. ; in the case of a moor, whether it is heather or grass, etc., and if so, which species.

(*b*) This will lead to the mapping out of the given district into areas. It may be found in the case of a wood that, although the prevailing tree is beech, in some parts of the wood where the trees have been less thickly planted there are shrubs forming a thick undergrowth, and in any case the fringe of the wood will yield different results ; thus there would probably be at least three areas in a beech-wood which would yield three different Plant Associations :

(i.) Area of wood where the trees are thick ;

(ii.) Area of wood where the trees are thin and undergrowth considerable ;

(iii.) Area along fringe of wood.

(*c*) Having mapped out the district into areas, these should be indicated *on the spot* on a good field-map. The Ordnance Survey maps are the best to use. The scale of the map will depend on the number of areas determined on in the district selected, and the extent of each. In the case of woods, the scale of 25 inches to the mile is the best, as the paths are marked and the kind of tree. Every plant found should be recorded on the spot in a note-book kept entirely for field work, with the exact date of finding.

(*d*) Having determined the dominant species, the subordinate forms should be noted, as well as any signs of a struggle going on between the subordinate and dominant species, and the relation of plants to each other. In a beech-wood saprophytic plants will probably be found. To carry out this part of the investigation, a certain knowledge of botany is necessary, but even beginners in the subject can notice certain facts which are indications of the dependence of one plant on another. When a plant is not green, but colourless, it is probable that it is either parasitic or saprophytic; then it should be ascertained on what plant it is growing, or on what substance it is feeding. After some experience observers get to notice that certain plants are commonly found together, and thus after a time, from the facts observed, it is possible to generalize.

(*e*) The physical features of the district and of each area mapped out should be recorded in the note-book:

(i.) Character of soil. A good geological guide of the district should be consulted; the most accurate information about a district is generally found in the *Transactions* of Local Scientific Societies.

(ii.) Slope of the district.

(iii.) Water-supply, by river, lake, etc.; rainfall.

(iv.) Prevailing wind.

(v.) Purity of atmosphere; freedom from smoke, etc.

(*f*) To ascertain which plants are peculiar to the district in question, the list of plants obtained in a given district should be compared with those obtained in other districts, and a fresh list made of those which do not occur in other districts. The new list may be very small indeed; it will depend on what districts are compared with each other. Thus if a moor in the South of England is being compared with a moor in Scotland, where the latitude and altitude may be very different, there will probably be considerable difference in the floras. Or, again, if the vegetation of the seashore is being compared with that of an inland district, there will be far greater differences than if two inland districts are being compared with each other.

II. Observations on the Adaptation of Plants to Habitat.

The vegetative organs of a plant—root, stem, leaf—are the most affected.

(*a*) The plants peculiar to the district should be compared with each other. Thus, if plants by the seashore are being observed, those known to grow elsewhere should be placed on one side, and those growing by the sea alone examined.

(i.) Length of roots, or underground stems, should be noted.

(ii.) Character of stem, whether creeping, stunted, prickly.

(iii.) Character of leaf. This is usually the organ most affected. The external characteristics of the leaf, whether thick and fleshy, or thin, prickly, smooth, or hairy; the colour of the leaf; the difference between the upper and under side; the angle at which light falls on the leaf, and the arrangement of leaves on the stem in connection with the amount of light each leaf in consequence obtains should all first be noted. Then microscopical examination of the leaf should be made, in order to ascertain the position of the stomata—whether on one surface, if so, on which, or on both surfaces. The manner of folding or inrolling of the leaf in connection with the presence of the stomata is also important.

(*b*) In order to ascertain how far the characters noted are due to environment, the growth of the same species under different surroundings should be compared. For example, Rest Harrow, when growing inland or by the sea, in a valley or on a hill. Drawings should be made, or the plant dried in sand—(this is better than pressing)—for future comparison.

III. The Influence of Man.

(*a*) The effect of thinning trees in a wood on its undergrowth. This is very noticeable. Lists should be made before thinning, and for two or three years afterwards.

(*b*) The effect of draining on swampy ground. This in time leads to the disappearance of plants.

(*c*) The effect of cultivating ground that has formerly been uncultivated. The weeds that appear in the cultivated ground should be noticed.

IV. Influence of Animals.

(*a*) Effect of absence of insects owing to severe frost. This will probably be seen in a lessened number of fruits and, ultimately, of plants.

(*b*) Effect of abundance of insects on pollination, etc.

(*c*) Effect of birds on dispersion of fruits and seeds.

(*d*) Result of introducing certain animals into pastures.

V. Observations on Seashore Vegetation.

(*a*) The plants found in shifting sand—that is, sand blown about by the wind, so that the plants are often covered up, and have to push their way up again.

(i.) The grasses binding the shifting sand together should be noted.

(ii.) An exact list should be made of the herbs found in the shifting sand at the level of the sea, where the sand is wet at every tide, and also above the level of the sea water, as, for instance, the shifting sand in the clefts of rocks.

(*b*) The plants found in the firmer sand, which is being built up by the grasses into sand-dunes. The herbs found here are far more numerous. Their general characteristics should be noted, and compared with the same plants found inland.

PART II

HISTOLOGY

CHAPTER VI

INTRODUCTION TO PLANT HISTOLOGY

Definition of Histology. HISTOLOGY (Gk. *histos*, web, and *logos*, a discourse), deals with the minute structure of plants and animals; it necessitates the use of a microscope, and is thus marked off from *Anatomy* (Gk. *ana*, up, *temno*, to cut), which is the study of structures as far as they can be made out with the naked eye. The examination of any plant, or of any part of a plant, under the microscope shows that it consists of a cell, or cells, or of structures derived from cells.

Protococcus. The *Protococcus* may be taken as a type of a unicellular plant; it belongs to one of the lowest groups of plants, the Algæ, and may be obtained by taking from a roof-gutter, or trunk of a tree, some of the greenish growth present in the water or on the bark of the tree. When looked at under the microscope (Appendix A), Protococci are seen to have two forms: one without a cell-wall, and moving about by means of two delicate processes, called *cilia* (Lat. *cilium*, an eyelash). The absence of a cell-wall in this motile Protococcus shows that a cell-wall is not an essential part of a cell.

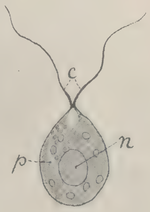

FIG. 5.—MOTILE PROTOCOCCUS.

p, protoplasm with chlorophyll granules; *n*, nucleus; *c*, cilia.

The other form of Protococcus is more or less stationary, and shows:

1. A *cell-wall*, consisting of a chemical substance called *cellulose*.

2. *Protoplasm*, in which may be seen a highly differentiated

portion, the nucleus, and colouring matter not uniformly distributed, but confined to certain definite portions of the protoplasm. The nucleus is best seen by staining the cell with iodine (Appendix A). The result of staining is that the cell-contents get brown, the chlorophyll bodies losing their green colour and becoming brown, whilst the nucleus gets a deep brown. After a little time, if enough iodine has been added, the protoplasm shrinks away from the cell-wall, which is then very clearly seen.

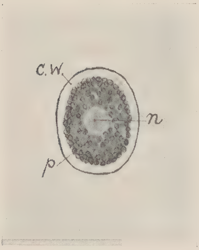

FIG. 6.—RESTING PROTOCOCCUS.

p, protoplasm with chlorophyll; *n*, nucleus; *c.w*, cell-wall.

3. The remaining portions of the cell, not filled with protoplasm but with cell-sap, are called *vacuoles* (Lat. *vacuus*, empty). The cell-sap also saturates the whole cell.

Each Protococcus cell, whether motile or stationary, is a living organism, able to perform all the functions essential to life ("Elementary Botany," pp. 111-114). The simplest forms of plant-life consist of living masses of protoplasm, each similar in its essential nature to that of Protococcus, and either naked or enclosed in a common cell-wall. *Vaucheria* is a type of the latter.

Vaucheria.

This Alga is often found growing like a green felt on the soil in pots in greenhouses, and is of a dull green appearance.

Vaucheria consists of very many masses of protoplasm enclosed in a common wall. It cannot be described as a unicellular plant, for many nuclei are present in its protoplasm, although they are unevenly distributed. At the same time, it would be incorrect to apply the term "multicellular" to it, for usually there are no cell-walls separating the various masses of nucleated protoplasm from each other. An organism of this kind is termed a *Cœnocyte* (Gk. *koinos*, common, *kutos*, a cell or vessel).

Vaucheria shows considerable differentiation: (1) It has an organ of attachment which answers in part to a root, although it has not the structure of the root of higher plants. (2) The shoot is often much branched, some branches being modified into organs of reproduction or attachment, as in the rooting portion. Chlorophyll is present in oval or spindle-shaped bodies, suspended in the protoplasm. Vaucheria, though not multicellular, is an advance on Protococcus, for, owing to the greater differentiation, more division of labour is possible.

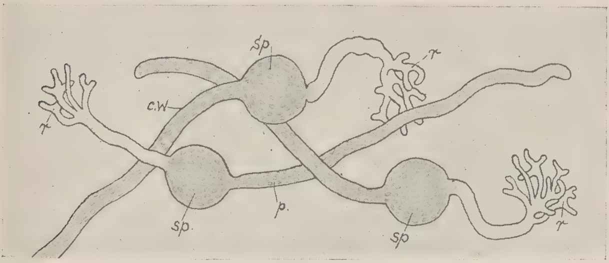

FIG. 7.—VAUCHERIA.

p, protoplasm with chlorophyll; *c.w*, cell-wall; *sp*, spore; *r*, organ of attachment.

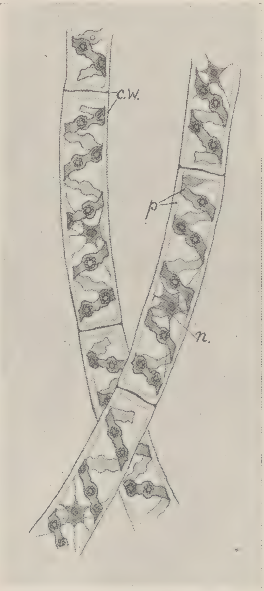

FIG. 8.—SPIROGYRA.

p, protoplasm with spiral bands of chlorophyll; *n*, nucleus with connecting threads of protoplasm; *c.w*, cell-wall.

Spirogyra. The fresh-water Alga, *Spirogyra*, may next be studied. It is found in ponds, in company with many other Algæ, which form the green, slimy growth on the surface of the water. If some of this green substance is placed on a glass slide, and the threads separated from each other with needles, filaments like the one drawn in Fig. 8 will be almost certainly found amongst the material. This is Spirogyra; it consists of cells, all exactly alike, each having the same essential structure described in Protococcus. Cell-walls are present between the cells, so that Spirogyra is multicellular. The portion of the protoplasm containing chlorophyll takes the form of spiral bands, hence the name. In this organism many cells are associated together; each cell is capable of all the activities necessary to the life of a plant, such as breathing and the taking in of food material; there is no setting apart of a particular cell for any special work. The cells have the power of dividing, each growing half into a cell like the original.

Fucus. If now the ribbon-like brown seaweed *Fucus* be examined, it will be found that it has a far more complicated structure than Spirogyra.

Fig. 9 is part of a section through the shoot. The cells forming the outer layers are very different from those of the inner layers. Here, then, it is clear that there is a setting apart of certain cells for special work—in fact, there is division of labour; the outer cells protect the inner, which are mainly concerned with the vital activities of the plant. A group of cells thus set apart for a particular work in the life of the plant is called a tissue. The cells

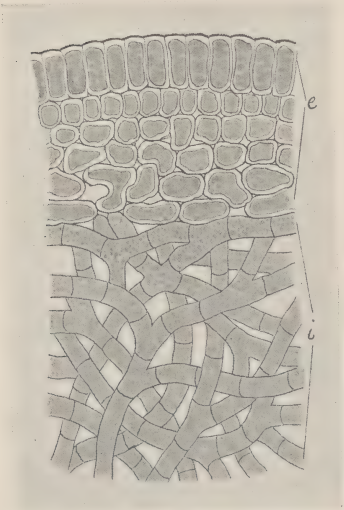

Fig. 9.—Fucus.

e, external protective layers; *i*, internal, looser tissue.

forming a tissue always have a common origin; they are interdependent; they act together in order to perform some definite work for the life of the plant as a whole, and their mode of growth is similar. There may be a considerable amount of differentiation, even in such lowly organised plants as the Algæ. This is well illustrated in the seaweed *Laminaria.* Fig. 10 gives part of a section of the shoot, which is easily seen to be much more differentiated than that of Fucus.

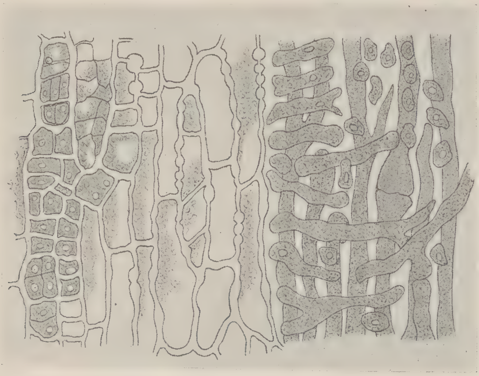

Fig. 10.—Laminaria.

All these instances, taken from one of the lowest groups of plants, the Algæ, show how tissues arise by differentiation. It is just this capability of division of labour which marks off a higher from a lower plant; we shall therefore expect to find many more tissues in Flowering Plants than in these Algæ.

Tissues of Flowering Plants. The cells of which a Flowering Plant consists are either—

1. *Meristematic* (Gk. *merizo*, to divide) cells, similar to those found in Protococcus and Spirogyra, capable of division and, therefore, of forming new cells; or

2. *Permanent* cells, which have lost the power of growth and which have become arranged in groups—*i.e.*, tissues—each with its definite work.

The staminal hairs of *Spiderwort* (Tradescantia) are an instance of meristematic cells. These hairs are purple, and offer a striking contrast to the yellow anthers. Under the microscope a hair is seen to consist of several cells, each showing a cell-wall, protoplasm with nucleus, and vacuoles filled with cell-sap. The cell-sap, which is purple, saturates the whole cell, and if it is a warm day, or if the slide is gently warmed, the streaming movement in the strands of protoplasm may be seen. They gradually change their shape, growing wider in one place and narrower in another. Groups of meristematic cells capable of growth and of dividing to form new cells are found at all growing points, where they contribute to growth in length, as at the apex of the root and stem. Meristematic cells also occur where growth in thickness, as in stems, is taking place; such cells form the tissue known as cambium.

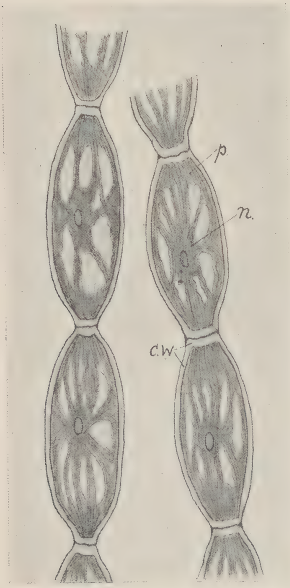

FIG. 11.—HAIRS OF TRADESCANTIA.

p, protoplasm; *n*, nucleus with threads; *c.w*, cell-wall.

Formation of Permanent Tissues. The formation of the permanent tissues of a flowering plant is due to the changes that take place:

(i.) In the shape of a cell;

(ii.) In the thickness of the cell-wall and its chemical composition;

(iii.) In the unions of cells with each other.

If the cells of a tissue remain about the same width in all directions, the tissue is called *parenchyma*. This tissue forms the groundwork of plants, and is largely concerned in the vital activities of the plant, especially with nutrition. If, however, the cell gets longer than it is broad, the tissue is called *prosenchyma*. As these cells grow their ends become pointed and their walls thickened, then fibres are formed. These prosenchymatous fibres are chiefly found in those tissues whose function it is to support the plant.

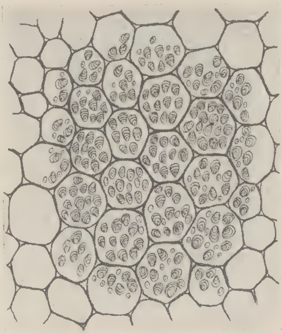

Fig. 12.—Cells of Parenchyma, containing Starch Grains.

The changes that take place in the thickness and chemical composition of the cell-wall are mainly of three kinds:

(*a*) A substance, called *lignin*, may be deposited in the cell-wall; then the cells are gradually converted into wood. This takes place more or less in all flowering plants. A cell-wall which has become lignified is very permeable, so that it easily allows of the passage of water. A thin slice of a wooden match, examined under the microscope, shows cells with lignified walls.

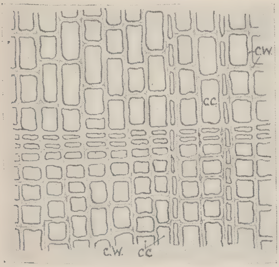

Fig. 13.—Wood of Match. *c.w*, lignified cell-wall; *c.c*, cell-cavity.

(*b*) The cell-wall may become *suberised* (Gk. *suber*, cork), then cork is formed. This tissue is not permeable, so that it is found in those parts of a plant which are exposed to the air, and which protect the inner tissues. Cork is, therefore, largely found in the stems of woody plants, in the trunks of trees, etc. A thin slice of bottle-cork shows the shape and appearance of cork cells. In the case of both wood and cork, it should be noticed that the cells have lost their protoplasmic contents, and that they are of use to the plant chiefly owing to the mechanical properties of their cell-walls.

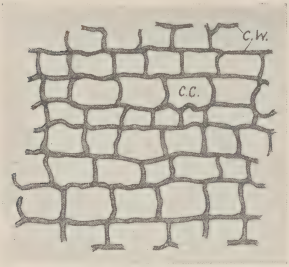

Fig. 14.—Slice of Bottle-Cork.
c.w, cell-wall; *c.c*, cell-cavity.

(*c*) Sometimes, instead of cork, the cell-walls become cuticularised (Lat. *cutis*, skin.) In this condition they are still protective, for a thick cuticle is almost impermeable to water. The epidermis of some leaves, more especially those of Xerophytes, shows this very well (Fig. 43).

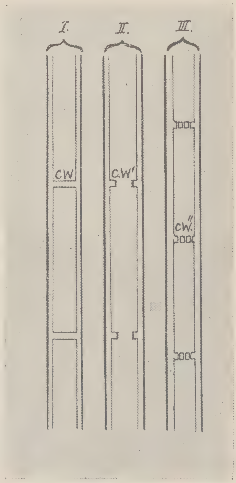

Fig. 15.—Diagram showing Formation of a Vessel and Sieve-Tube.

I, Row of cells; II, row in which cell-walls are absorbed; III, row in which cell-walls are perforated; *c.w*, cell-wall between adjacent cells; *c.w'*, cell-wall absorbed; *c.w''*, cell-wall perforated.

The changes that take place in a row of cells lead to the formation of *vessels*. If a number of cells (as in Diagram I. of Fig. 15) occur one above the other, and the cell-walls which touch each other gradually become thinner and thinner and ultimately disappear, then the cavities of the cells will communicate with each other and a vessel will be formed, as in Diagram II. It is vessels for the most that have lignified walls. The thickening of the cell-walls of vessels may be laid down in various ways—sometimes spirally, or in rings, or like the steps of a ladder, so that there is a considerable variety of vessels, as will be seen in the next chapter; sometimes the cell-walls between the cells do not entirely disappear, but are merely perforated with holes, so that the contents of one cell can pass into the adjoining one, as in Fig. 15, III. The cell-wall then remains as a plate. This form of vessel is known as a *sieve-tube*, and the perforated cell-wall is called a *sieve-plate* (see Fig. 16).

In one or other of the ways just described tissues are formed. Although each tissue has its definite and special work to do, it must never be forgotten that a plant is a living whole, each tissue contributing to the health and general well-being of the organism.

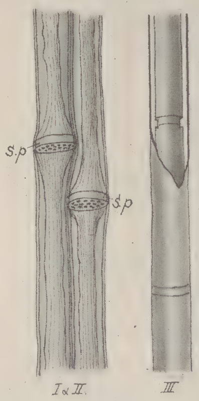

FIG. 16.—DIAGRAM SHOWING SIEVE-TUBES IN WOOD VESSEL.

I, II, Sieve-tubes with sieve-plates; *s.p*, sieve-plate; III, a wood vessel with portion of wall removed to show interior.

SUMMARY.

1. All plants, and all parts of a plant, consist of cells.

2. Cells are grouped together into tissues by a process of differentiation, each tissue having its special work.

3. Tissues may be divided into—
    - (*a*) Meristematic—those which retain the power of growth.
    - (*b*) Permanent—those which have lost the power of growth.

4. The changes by which Meristematic tissues are converted into Permanent are—
    - (i.) Change in shape of the cell, the tissue formed being either parenchyma or prosenchyma.
    - (ii.) Change in the thickness and chemical composition of the cell-wall, as in lignified wood cells and in cork cells.
    - (iii.) Change in cell-unions, by which vessels are formed.

CHAPTER VII

THE STEM

Structure of Growing Point. THE stem of a growing plant consists of meristematic and permanent tissues. The former are found at the apex of the stem, for this is its growing point; they also occur wherever growth in thickness is taking place. A median longitudinal section through the growing point of a stem shows cells, which are all somewhat similar, thin-walled, and rich in protoplasm, constantly dividing, and thus giving rise to new cells. Almost immediately behind the apex these cells are seen to be arranged in three groups or tissues :

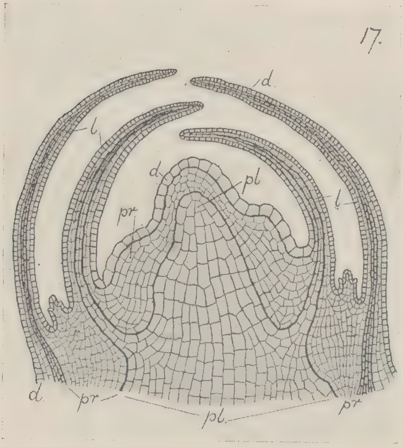

FIG. 17.—APEX OF STEM, MEDIAN LONGITUDINAL SECTION. (High power, diagrammatic.)

d, dermatogen ; *pl*, plerome ; *pr*, periblem ; *l*, leaves.

1. A central tissue, composed of rather larger cells, with thin walls. This is called the *plerome.*

2. On each side of this the cells are smaller and in shape oblong. This is the *periblem.*

3. The external layer consists of more or less square cells,

the outer wall of which is slightly thickened. This is the *dermatogen.*

From these three primary layers of the growing point arise the three great permanent tissue systems of the adult stem.

The plerome gives rise to the *stele*—that is, to everything within the cortex, the inner layer of which is called the bundle-sheath; the periblem on each side gives rise to the *cortex*, whilst the dermatogen produces the *epidermis.*

These may next be examined in a young Sunflower, which may be taken as a typical herbaceous stem of a mesophytic plant.

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Stem of Sunflower. Cut the stem of a young Sunflower through one of the internodes, and observe with the naked eye. Fig. 18 represents a drawing made under a low power of the microscope.

The most conspicuous part will be the white spongy pith in the centre. This is parenchymatous tissue. Around that, arranged in a circle, is a yellowish-white, fibrous-looking tissue. These are the fibro-vascular bundles; the spaces between are the medullary rays, and consist of parenchymatous tissue. Outside this ring of fibro-vascular tissue follows some more parenchymatous tissue, forming the cortex of the stem, and outside of all a skin, the epidermis. Thus with the naked eye it is possible to make out the three chief forms of tissue in stems, namely, the epidermis, the parenchyma, and the fibro-vascular tissue. The minute structure is explained later.

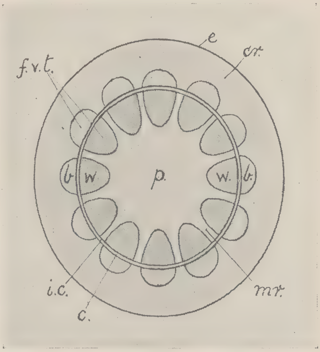


FIG. 18.—STEM OF SUNFLOWER, TRANSVERSE SECTION. (Low power, diagrammatic.)

e, epidermis; *cr*, cortex; *f.v.t*, fibro-vascular tissue; *b*, bast; *w*, wood; *m.r*, medullary rays; *p*, pith; *c*, cambium; *i.c*, interfascicular cambium.

Stem of Lime.

With the Sunflower may be compared a twig of the Lime, or Elm, or Oak, or any woody stem. A twig three or four years old should be chosen; the age of a twig can be told by noticing the scars left by the scales of the buds of each year ("Elementary Botany," p. 15). Cut a twig of the Lime across, and observe with the naked eye, as before. The same tissues are observable as in the Sunflower, but it will be seen at a glance that the fibro-vascular tissue does not occur in isolated bundles, as in the Sunflower; instead of that a cylinder of wood has been formed. It will be easy to recognise the three rings of wood, corresponding to the three years of growth, and the medullary rays between the wood. In this stem the greater part of the section is occupied with the wood; the pith is much less than in the Sunflower, considering the size of each. Beneath the outer skin may be seen a yellowish tissue, which is cork.

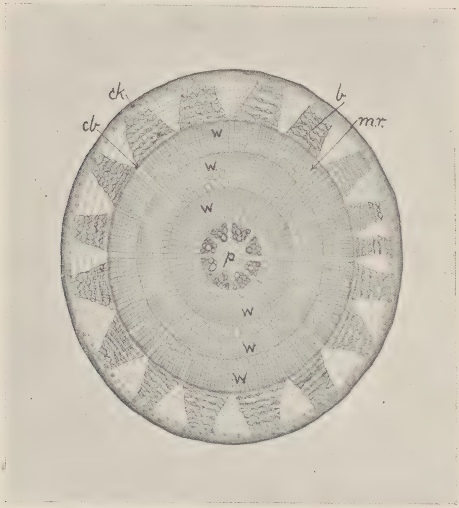


Fig. 19.—Stem of Three-Year-Old Twig Lime, Transverse Section. (Low power.)

ck, cork; *b*, bast; *w*, wood; *p*, pith; *cb*, position of cambium; *m.r*, medullary rays.

Course of Fibro-Vascular Tissue.

The course of the fibro-vascular bundles through the stem must next be considered. It is easier to trace them out in the Dead-nettle than in the Sunflower, for they are less complicated, but even in the Dead-nettle it is not easy. A length of stem including at least three internodes is necessary; boiling the stem for two or three minutes makes it easier to remove the cortex. The stem should be put into a solution of aniline sulphate; the fibro-vascular tissue is then stained yellow, and is more easily traced. The cortex should be carefully removed with needles or scraped with a knife; then the vascular tissue is exposed, and can be traced through the length of the stem and into the leaves.

Fig. 20 is a transverse section through the *internode* of the stem of the Dead-nettle. There is no difficulty in recognising the eight bundles, three on each side of the two leaf-bearing sides of the stem, and one in the middle of each side of the stem which does not bear leaves. It must be borne in mind that the leaves of the Dead-nettle are opposite and decussate.

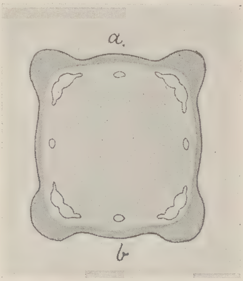


Fig. 20.—Internode of Dead-nettle, Transverse Section. (Diagrammatic.)

a, *b*, leaf-bearing sides.

Fig. 21 is a transverse section through the *node* of the stem of the Dead-nettle, and there, instead of eight bundles, sixteen are seen. At the node the leaves arise, this section therefore shows the bundles of the leaf before they have fused with those of the stem. To understand the arrangement thoroughly the bundles must be traced lengthways. In Fig. 22 the cortex has been removed, and the longitudinal course of the bundles can then be traced.

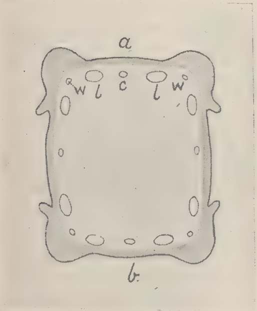


Fig. 21.—Node of Dead-nettle, Transverse Section. (Diagrammatic.)

a, *b*, leaf-bearing sides; *c*, central bundle; *l*, lateral bundles; *w*, wing bundles.

It will there be seen that

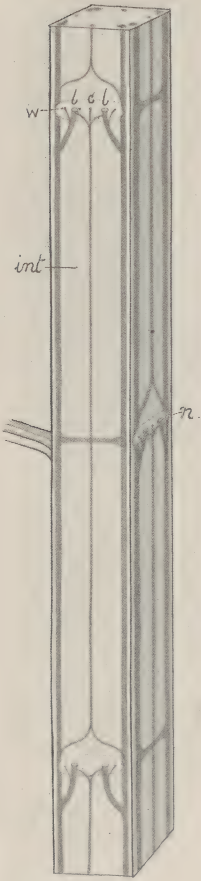


FIG. 22.—STEM OF DEAD-NETTLE, CORTEX REMOVED. (Diagrammatic.)
n, node-bearing leaves; *int*, internode; *c*, central bundle; *l*, lateral bundles; *w*, wing bundles.

the central bundle (*c*) of each leaf-bearing side of the stem passes down through two internodes. This central bundle is the median bundle of the leaf. At the node where there is no leaf on its side of the stem it simply joins by short transverse trunks the bundles on each side of it; but when the second node, that bearing a leaf, is reached, the bundle forks and its branches fuse with the same two lateral bundles. Two other bundles, called wing bundles (*w*), are seen at the node, one on each side of the lateral leaf-bundle. A transverse section of the petiole of the leaf shows also five bundles, one central, two lateral, two wing (Fig. 23).

It is also clear from Fig. 22, that the single corner bundle in Fig. 20 consists of two lateral bundles, one from each side of the stem. It will be seen from what has just been said that in the Dead-nettle the bundles are common to stem and leaf. In some cases, however, the bundles of the stem do not terminate in the young leaves, but in the growing point of the stem; these bundles are said to be cauline, because they belong to the stem alone. As a rule the bundles of Dicotyledons run longitudinally and parallel to each other. It need hardly be said that the bundles of root, stem, and leaf are continuous with each other.

Structure of Stem of Sunflower under Microscope.

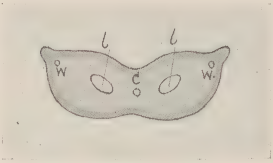


FIG. 23.—PETIOLE OF DEAD-NETTLE, TRANSVERSE SECTION. (Diagrammatic.)

c, central bundle; l, lateral bundles; w, wing bundles.

In order to study the minute structure of a stem, very thin sections must be prepared and examined under the microscope (Appendix A.). It will then be seen that the cells of the epidermis of the Sunflower are almost square, have cuticularised outer walls, and no cell-contents. They are entirely protective. The cells of the cortex next the epidermis are thin-walled, with large cavities, and vary very much in size and shape; where the walls of two or three cells meet they are thickened. The cells of the innermost layers of the cortex have not this thickening, and are parenchymatous.

The *fibro-vascular tissue* consists of bast, cambium, and wood; the bast and wood are parallel to each other, and the arrangement is known as collateral (Fig. 18). The boundary of the stele is clearly marked out by the *bundle-sheath*, or *endodermis* (Plate III., *end*), a layer of cells rather longer than they are broad, and containing starch. Within this comes a layer of fibres, which may be distinguished from the underlying cells by the rather thicker walls. These fibres are developed from the layer which immediately surrounds the central cylinder of vascular tissue, and is therefore called the *pericycle* (Gk. *peri*, round); the fibres are known as the *pericycle fibres.* Within this comes the true fibro-vascular tissue, consisting of bast, cambium, and wood. The external layer of the *bast*, that next the pericycle, consists of prosenchymatous tissue, known as *bast fibres*. This is a supporting tissue, by means of which, partly, the plant maintains its upright position against strong winds, etc. These two sets of fibres, the pericycle and bast, which are very similar to each other, together offer strong resistance to mechanical forces. Even when most delicate they are found to be very tough and difficult to tear;

it is from the pericycle fibres of different plants that hemp, flax, and kindred substances are manufactured. Within the bast fibres, among the bast parenchyma, will be seen the *sieve-tubes* (*s.t*). These are formed in much the same way as vessels, with this difference: the cell-walls between the adjoining cells do not entirely disappear, but become perforated, so that if the section passes through the cavity of the sieve-tube it appears round and hollow, just as a vessel would do; but if it passes through the perforated wall, this appears as a plate within the vessel, and in a transverse section of the stem has a punctate appearance (*s.p*). Each sieve-tube has in connection with it quite small cells, rich in protoplasm and with a well-marked nucleus. They are called companion cells; they are distinguished from the cells forming the bast parenchyma by their small size. It will now be clear that in a sunflower stem bast consists of—

1. Bast fibres; these are prosenchymatous.
2. Sieve-tubes with companion-cells.
3. Bast cells, or bast parenchyma.

It is through the sieve tissue that the nitrogenous food passes from one part of the plant to another.

The *cambium* (*cb*) consists of meristematic cells, arranged regularly one above the other, longer than they are broad, with very thin walls. The function of the cambium will be explained later in connection with the growth of the stem in thickness.

The *wood* of a fibro-vascular bundle, like the bast, consists also of fibres, cells, and vessels, but there is this important difference: in the wood these structures have been thickened by *lignin*, so that the cell-walls do not merely consist of cellulose, as in the bast, but have become lignified. The wood vessels are practically hollow tubes, conducting water and substances in solution in it through the plant; whereas the sieve-tubes are not complete tubes, owing to the sieve-plates. In a transverse section the vessels are cut

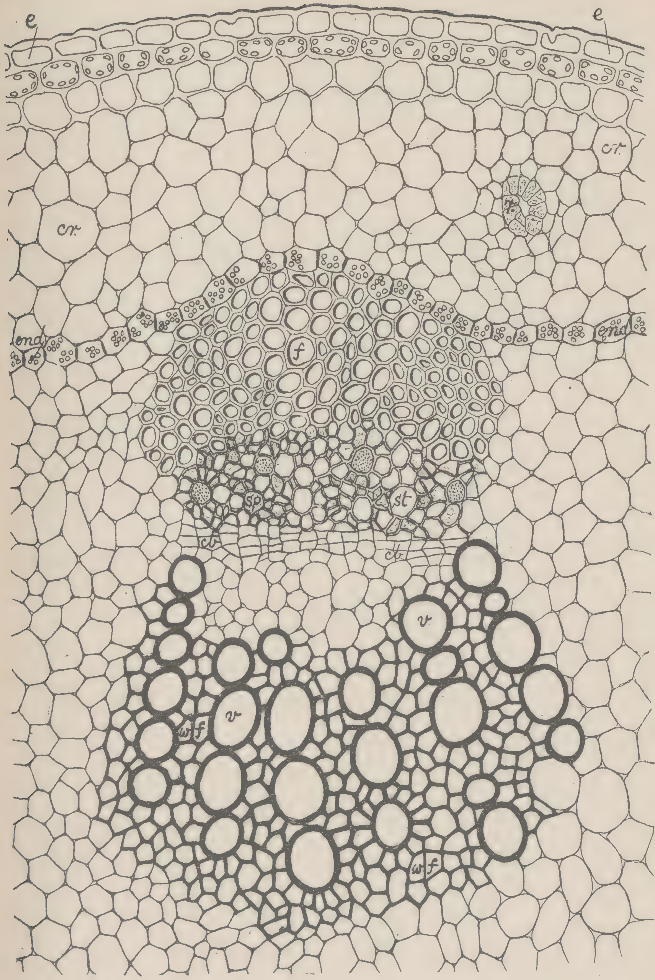


PLATE III.

Fig. 24.—Sunflower, Fibro-Vascular Bundle, Transverse Section. (Very high power.)

e, epidermis ; *cr*, cortex ; *r*, resin duct ; *end*, endodermis ; *f*, fibres of pericycle and bast ; *s.t*, sieve-tube ; *s.p*, sieve-plate ; *cb*, cambium ; *v*, vessels ; *w.f*, wood-fibres ; *c*, companion cells.

across, so that their thickened walls appear as a double ring. In a longitudinal section of the stem, however, the vessels are cut lengthways in half, so that the thickening of the cell-wall is seen in surface view.

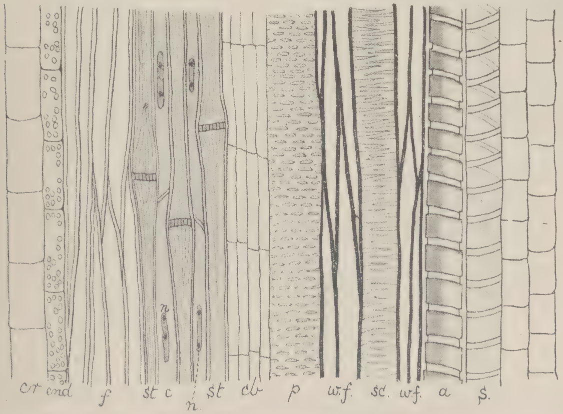


FIG. 25.—SUNFLOWER, FIBRO-VASCULAR BUNDLE, LONGITUDINAL SECTION. (High power, somewhat diagrammatic.)

cr, cortex ; *end*, endodermis ; *f*, fibres of pericyle and bast ; *s.t*, sieve-tube ; *c*, companion cells ; *n*, nucleus ; *cb*, cambium ; *p*, pitted vessel ; *w.f*, wood fibres ; *sc*, scalariform vessel ; *a*, annular vessel ; *s*, spiral vessel.

If the lignin were deposited in equal thickness over the whole cell-wall, then there would be no special markings ; but the lignin is more thickly laid down in some places than in others. Sometimes the part of a cell-wall thus thickened is spiral in outline, then the vessel is called a spiral vessel (Fig. 25, *s*) ; and sometimes the thickening is laid down at intervals in rings, then the vessel is annular (*a*). Very often the thickening is laid down over the whole cell-wall, leaving little gaps called pits, so that the cell-wall looks studded with depressions ; these are the thin places where the lignin has not been deposited. Such a vessel is said to be pitted (*p*). The wood-fibres are prosenchymatous, and the wood-cells parenchymatous. The wood of the Sunflower thus consists of :

1. Wood-vessels—spiral, annular, pitted ;
2. Wood-cells, or wood parenchyma ;
3. Wood-fibres, or wood prosenchyma.

Growth in Thickness. The stem increases in thickness by means of the cambium ; this meristematic tissue forms bast and wood in the following way :

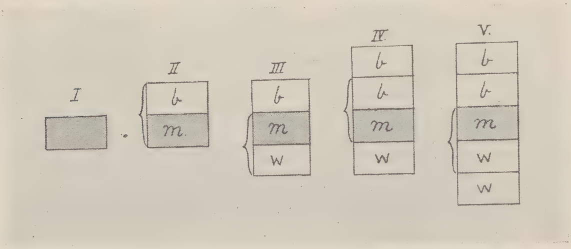


Fig. 26.—Diagram illustrating Formation of Secondary Bast and Wood from Cambium.

I, A single cambium cell. II, *m*, meristematic cell ; *b*, bast. III-V, *m*, meristematic cell ; *b*, bast ; *w*, wood.

Let I (Fig. 26) be a single cambium cell ; this divides into two. There does not appear to be any fixed rule which of these two cells will next divide. If the inner—that is, the one nearest the wood—retains the power of dividing, then the outer forms bast (II, *b*). This inner cell then divides into two cells, the outer of which will retain the power of dividing, (for the cells take it in turn to divide), and the inner becomes wood (III, *w*). The outermost cell next divides into two, the inner of which retains the power of dividing, the outer becoming bast. In this way secondary bast and secondary wood are formed. Sometimes, instead of forming wood and bast, the cambium gives rise to rows of thin-walled cells, which form the medullary rays. Cambium is especially active in the spring, but the formation of bast and wood goes on through the summer into the autumn. The wood formed in autumn is more compact than that formed in spring, and as the spring wood of one year comes next the autumn wood of the previous year, the rings can be seen with the naked eye, and the age of the tree detected. Secondary wood and bast must be distinguished from primary, as their origin is different. The wood and bast formed from the meristematic tissue at the growing point is known as primary; that formed from the activity of the cambium, as just described, is secondary.

In a young stem the bundles are isolated, but as development proceeds a layer of cambium arises between the bundles; it becomes united with the original cambium of the bundle, so that a complete cambium ring is formed. The cambium between the bundles is distinguished as *interfascicular*. This, too, gives rise to wood and bast, so that if a section of a stem is made in which this process is going on, young bundles will be seen between the first-formed bundles, which after a time grow as large as the original bundles; ultimately the bundles become united, forming a complete ring, as in Dicotyledons.

Comparison of Monocotyledons and Dicotyledons.

In Monocotyledons the bundles do not form a complete ring; the stems of these plants do not increase in thickness, so that the cylindrical arrangement of the bundles found in Dicotyledons is not so necessary in their case. Monocotyledons are lower-growing plants, and do not therefore need to offer so much resistance to the force of the wind as many Dicotyledons do; the bundles are scattered, not in a ring.

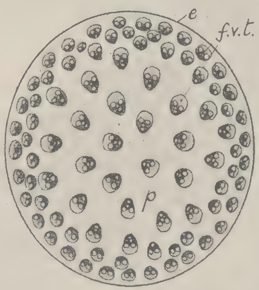


FIG. 27. — MONOCOTYLEDONOUS STEM, TRANSVERSE SECTION. (Low power, diagrammatic.)

e, epidermis; *f.v.t*, fibro-vascular tissue; *p*, ground tissue of parenchyma.

As the stems do not increase in thickness, there is no necessity for a layer of meristematic cells once the bundles are formed, so that in Monocotyledons there is no cambium; the bundles are said to be closed. As in Dicotyledons, each bundle consists of bast and wood. The wood is towards the centre, and the arrangement of the vessels is V-shaped.

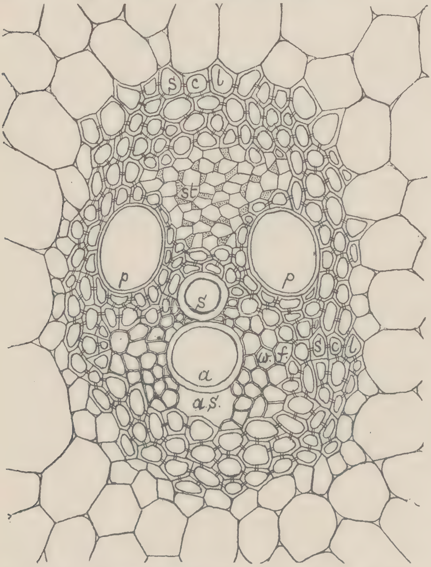


Fig. 28.—Fibro-vascular Bundle of Monocotyledon, Transverse Section. (High power.)

p, pitted vessel; *s*, spiral; *a*, annular; *a.s*, air space; *s.t*, sieve tubes; *w.f*, wood fibres; *scl*, sheath of fibres.

Formation of Cork. Cork is formed usually immediately beneath the epidermis. As the stem grows in thickness, the underlying tissues grow faster than the epidermis, which becomes torn, and therefore not a sufficient protection to the softer tissues underneath. Even in herbs this is the case, and then cork cells are formed.

Generally a layer of the cortical parenchyma immediately beneath the epidermis begins to divide, and is then called *cork cambium* (Fig. 29, *c.c*). This gives rise to layers of cells, which form

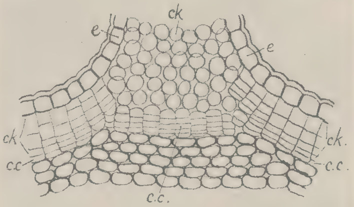


Fig. 29.—Open Lenticel, Transverse Section. (High power.)

c.c, cork cambium; *ck*, cork; *e*, ruptured epidermis.

on the outside cork, whilst on the inside it adds to the cortical tissue. As cork does not allow of the passage of water, it follows that the tissues outside the cork are cut off from the supply of water, and wither; the term "bark" is applied to all the dried-up tissues outside it. These may include different tissue-systems and cells of different forms.

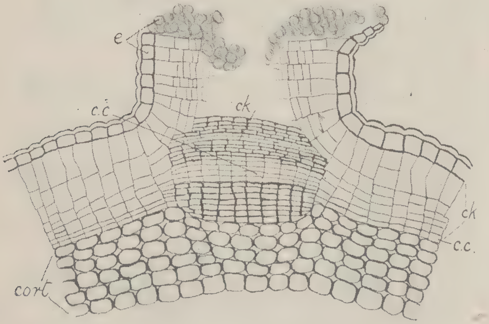


Fig. 30.—Closed Lenticel, Transverse Section. (High power.)
c.c, cork cambium; *ck*, cork; *e*, ruptured epidermis; *cort*, cortex.

If the cork formed a thick ring all round the wood of the tree it would be impossible for the oxygen of the air to reach the cells inside. Special structures, answering to stomata, are formed in the cortex; these are called *lenticels*.

Lenticels which occur in branches of one year's growth look like brownish or whitish specks. They often originate just beneath the stomata and in cases where the cork is thick, they may form almost deep canals.

In the spring these lenticels are filled with cork cells, which are very loosely packed, so that gaseous interchange between the plant and external air is possible. In the winter these lenticels are closed; the cork cells which have no intercellular spaces are tightly packed, so as to exclude air (Fig. 30).

SUMMARY OF STEM TISSUES.

	Meristematic.		*Permanent.*
At Apex	1. Dermatogen	giving rise to	Epidermis.
	2. Periblem	,, ,,	Cortical Parenchyma and Endodermis.
	3. Plerome	,, ,,	Stele: Pericycle. Fibro-vascular tissue and medullary rays. Pith.
	Cambium	,, ,,	Secondary bast and secondary wood.

Stem of Xerophytes. The stem of a xerophytic plant differs in one or two well-marked particulars from the mesophytic stems just described.

Fig. 31 is a drawing of a transverse section of Salicornia, a plant growing on muddy sea-shores and in salt marshes. It has no leaves, so that the stem practically combines the functions of leaf and stem.

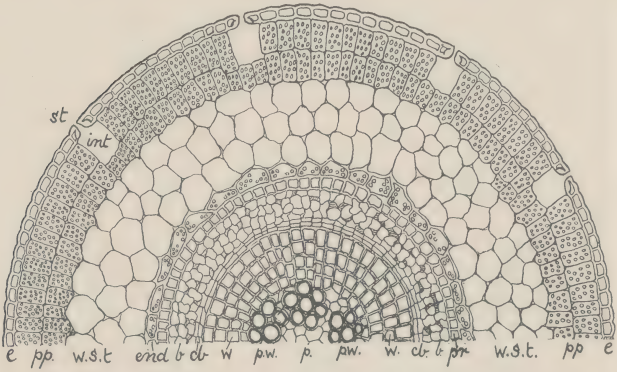


FIG. 31.—SALICORNIA, TRANSVERSE SECTION OF HALF A STEM. (High power.)

e, epidermis; *st*, stomate; *int*, intercellular space; *p.p*, palisade parenchyma with chlorophyll; *w.s.t*, water-storage tissue; *end*, endodermis; *pr*, pericycle; *b*, bast; *cb*, cambium; *p.w*, primary wood; *w*, secondary wood; *p*, pith.

The most striking features of this stem are:

1. The thick cuticle of the epidermis and the stomata, communicating with the intercellular spaces.

2. The layer of two rows of parenchymatous cells containing chlorophyll, immediately beneath the epidermis. These cells resemble those usually found beneath the upper epidermis of the leaf; they play an active part in assimilation.

3. The water-storage tissue. The cells of which this consists have thin walls and colourless cell-contents.

4. The fibro-vascular tissue, consisting of bast, cambium, and wood, is very much reduced compared with that of a Mesophyte. The wood is reduced because there is little transpiration; therefore conduction of water is not so necessary; then, the assimilating tissue being present in the stem, the bast is reduced, as the distance along which the food is to be conducted is short.

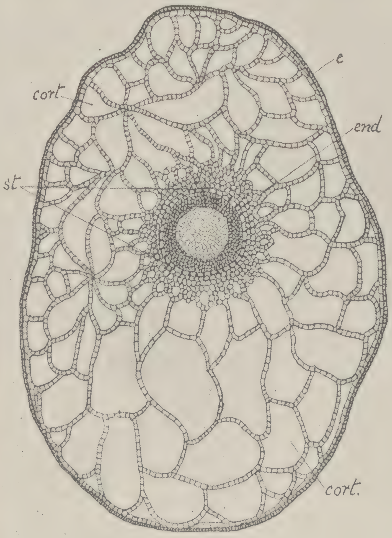


FIG. 32.—HIPPURIS STEM, TRANSVERSE SECTION. (Low power.)

e, epidermis; *cort*, cortical tissue with large intercellular spaces; *end*, endodermis; *st*, stele.

Stem of Hydrophytes. In the stem of aquatic plants the epidermis has either no cuticle or a very thin one. In Mare's-tail (*Hippuris vulgaris*) there is a thin cuticle.

The cortical parenchyma is characterised by very large intercellular spaces, which give lightness to the plant. The central vascular cylinder is very much reduced; the wood occupies a comparatively small portion of the stem, and shows a slight amount of lignification. In many water-plants lignin is not found in the walls of wood cells.

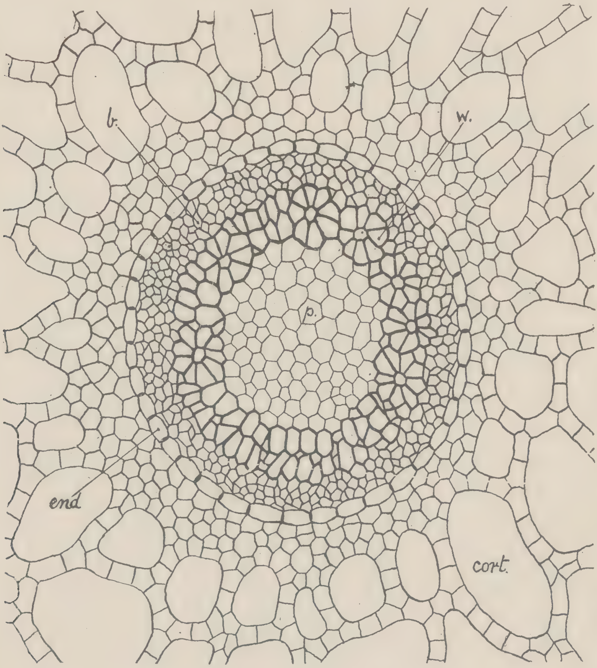


FIG. 33.—STELE OF HIPPURIS, TRANSVERSE SECTION. (High power.) *cort*, cortical tissue; *end*, endodermis; *b*, bast; *w*, wood; *p*, pith.

In one or other of these ways the minute structure of the stem is adapted to the habitat of the plant.

CHAPTER VIII

THE ROOT

Structure of Apex. If seeds of Maize are allowed to germinate in moist air, or if a Hyacinth bulb is grown in water, the tips of roots can be examined. It will be seen that each root is covered with a little shield, called the root-cap. Then, if a section is made longitudinally through the apex, the tissues of which it consists can be examined under the microscope. It will be at once evident that the cells of which the root-cap is composed are fully grown and differentiated to form a protecting tissue for the root; they are much larger than the adjoining cells, and are not giving rise to new cells. Within the root-cap the cells are small, thin-walled, and very similar to those already described at the apex of the stem. These cells are arranged in longitudinal rows, and converge just behind the apex; this is the growing point. It consists of meristematic tissue, which gives rise on one side to the root, on the other to the root-cap. The meristematic cells show differentiation into three tissues:

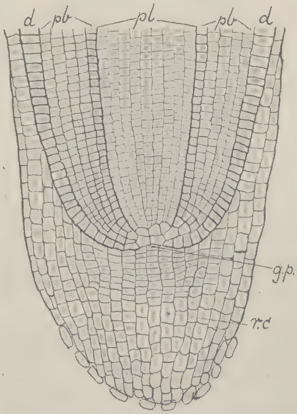


Fig. 34.—Apex of Root, Median Longitudinal. (High power, diagrammatic.)

r.c, root cap; *g.p*, growing point; *d*, dermatogen; *pl*, plerome; *pb*, periblem.

1. On the outside the *dermatogen*, which gives rise generally only to the root-cap.

2. In the centre the *plerome*, which forms the stele.

3. On each side of the plerome the *periblem*, giving rise to the cortex, the innermost layer of which forms the endodermis.

Structure as seen in Transverse Section. A transverse section of a typical Dicotyledonous root, made a little behind the growing point (such as that drawn in Fig. 35), shows the following tissues :

(*a*) An outer layer corresponding to the epidermis of the stem ; this is called the *piliferous* (Lat. *pilus*, a hair) layer in the root, because it bears hairs which are very conspicuous a little behind the tip.

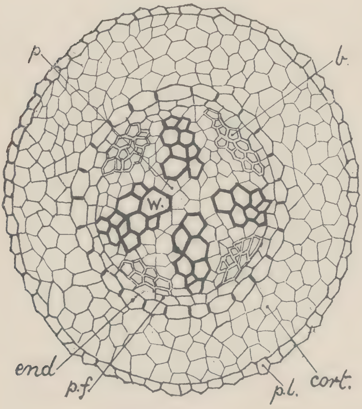


FIG. 35.—DICOTYLEDONOUS ROOT, TRANSVERSE SECTION. (High power.)

p.l, piliferous layer ; *cort*, cortex ; *end*, endodermis ; *p.f*, pericycle ; *w*, wood ; *b*, bast ; *p*, pith.

(*b*) Within that the *cortical parenchymatous* tissue, the inner layer of which is the endodermis, easily distinguished by the thickening of its side walls.

(*c*) The *stele* consists of : (i.) The pericycle ; (ii.) vascular tissue ; (iii.) pith. In a Dicotyledon the typical number of bundles in the root is four ; they consist of groups of cells, forming bast and wood, arranged alternately. As these groups of cells lie on alternate radii, the arrangement of the bast and wood is said to be *radial*. In a young root the wood is more distinct than the bast, and is nearer the centre.

If sections are made further from the apex, so as to pass through the lateral branches of a root, their mode of origin will be seen. The lateral roots arise opposite the groups of wood, and as there are four groups in a typical Dicotyledon, the lateral branches will be in four rows. It must be remembered that this number is not constant, but it is frequent; the point to note is that the number of rows of branches in a fully-grown root is the same as the number of groups of wood in a primary root. In Monocotyledons the number of bundles is greater than in a Dicotyledon. The branches arise from the *pericycle*, the cells of which divide, giving rise to the growing point of a young root, which pushes its way through the outer tissues, the cells on each side becoming broken down and gradually absorbed.

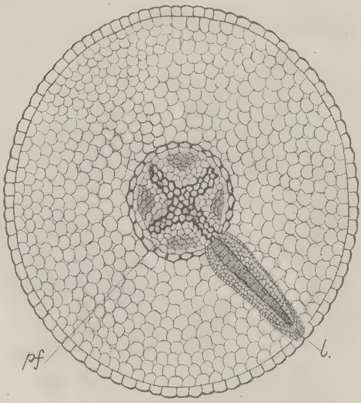


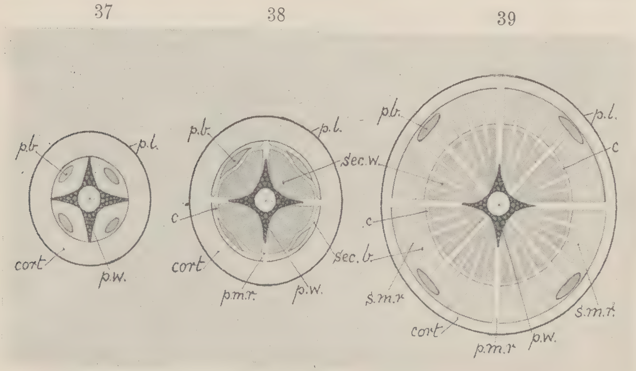
FIG. 36.—DICOTYLEDONOUS ROOT WITH LATERAL BRANCH, TRANSVERSE SECTION. (High power.)
p.f, pericycle; *l*, lateral root.

Growth in Length and Thickness. The root grows in length only just behind its apex. As soon as the young meristematic cells have grown to their full size they become permanent tissue, and do not grow any further.

Growth in thickness takes place in the older parts of the root owing to the formation of secondary wood and bast, which originate from the cambium formed as the root grows. In order to see this a series of sections must be made at intervals of an inch or two behind the tip.

Fig. 37 is a diagram showing the tissues in a young root, as already described. In this the bast alternates with the wood, and there is no cambium.

Fig. 38 represents, also diagrammatically, a section through that part of the root which has begun to turn brown and bears many lateral roots. In this the four groups of primary wood (*p.w*) still alternate with the groups of primary bast (*p.b*), as before. Between the bast and the wood cells undergoing division are seen; this is the cambial layer, which is giving rise to secondary bast (*sec.b*) and secondary wood (*sec.w*). This layer (*c*) arises in the pericycle opposite the wood, then spreads round outside the wood and inside the bast, so that first of all it forms a ring of wavy outline. It divides exactly as the cambium of the stem does, giving rise to secondary bast towards the outside, secondary wood towards the inside, and medullary rays (*s.m.r*) along certain radii. The cambium opposite the original wood groups gives rise entirely to medullary tissue, so that large broad medullary rays extend from the groups of primary wood to the pericycle.



Figs. 37-39.—Diagrams illustrating Formation of Secondary Wood and Bast in Dicotyledonous Roots.

p.b, primary bast; *p.w*, primary wood; *p.m.r*, primary medullary rays; *s.m.r*, secondary medullary rays; *sec.w*, secondary wood; *sec.b*, secondary bast; *cort*, cortex; *p.l*, piliferous layer; *c*, cambium.

Fig. 39 represents a transverse section of a root taken still further back from the growing point. Secondary growth has been going on for some time. The greater part of the section shows secondary wood, the primary wood having been pushed towards the centre; the primary bast, still alternating with the primary wood, has been pushed towards the circumference by the formation of the secondary bast within it; whilst between the bast and wood lies the cambium.

By the time this condition of things is reached the cortical parenchyma of the root has entirely disappeared, for the cells of the pericycle, which began to divide at the same time that the cambium was being formed, have developed a layer of cork, and the outer tissues have therefore become dried up.

The following table may be found useful:

COMPARISON OF ROOT AND STEM WHICH HAVE GROWN IN THICKNESS.

ROOT.	STEM.
1. The primary groups of wood and bast lie along alternate radii.	The primary groups of wood and bast lie along the same radii.
2. The protoxylem is the external part of the primary wood.	The protoxylem is the internal part of the primary wood.
3. Opposite each group of primary wood is a well-marked medullary ray, extending to the pericycle.	The primary medullary rays are not so well marked.
4. The groups of primary wood frequently unite across the centre, so that there is no pith.	Except in a few cases—chiefly water plants—there is a well-marked pith.

Longitudinal Course of Bundles.

From what has been said it will be gathered that the longitudinal course of bundles in the root is simpler than it is in the stem. The bundles are more or less straight, extending from the growing point backwards to where the root merges into the stem. From these bundles of the primary root other bundles passing into the lateral roots are given off. The course of bundles in the stem is more complicated, owing to the fact that leaves, the lateral outgrowths of the stem, are members unlike the stem, whereas lateral roots are in all respects similar to the main root. It must be remembered that, although the arrangement of bundles in the stem differs from that of the root, there is no break in the continuity of the tissues, for the wood bundles of the root twist on themselves, so that they come to be on the same radii as the bast bundles, and the protoxylem which was external in the root becomes internal in the stem. Besides that, the bundles of the root bifurcate, so that generally there are twice as many in the stem as in the root.

Adaptation of Structure to Function.

So far the roots of Mesophytes have alone been described; it will be seen that their structure is exactly adapted to the functions they have to perform, which are mainly three:

1. To fix the plant in the soil.
2. To absorb water and food-substances from the soil—the work of the root-hairs.
3. To conduct the substances thus absorbed to the stem—the function of the fibro-vascular tissue.

The structure of the roots of leguminous plants should be especially noticed. They have little swellings which are produced by a fungus. This fungus makes use of the free nitrogen of the atmosphere, building up some compound of nitrogen, which it hands on to the plant ("Elementary Botany," pp. 123, 124).

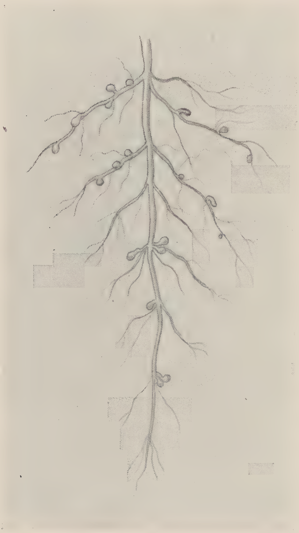


Fig. 40.—Leguminous Root.

The roots of Hydrophytes, where present, differ very much from those of Mesophytes; the wood and bast are very much reduced for two reasons: the plant has no strain to bear, and therefore does not need the support of these tissues; and, owing to its living in water and its whole surface being engaged in the absorption of food material, it does not need any tissue for the conduction and transpiration of water and food substances.

Xerophytes, on the other hand, often have well-marked tap-roots, which penetrate the soil in order to get water that is sometimes present at a great depth, for roots are attracted by the presence of moisture, and grow towards it.

CHAPTER IX

THE LEAF

Structure of Mesophytic Leaf.

THERE is no organ of a plant which shows more variety of structure, more power of adapting itself to its surroundings, than the leaf. Fig. 41 is a drawing of a transverse section of the lamina of the sunflower, which may be taken as a type of the mesophytic leaf.

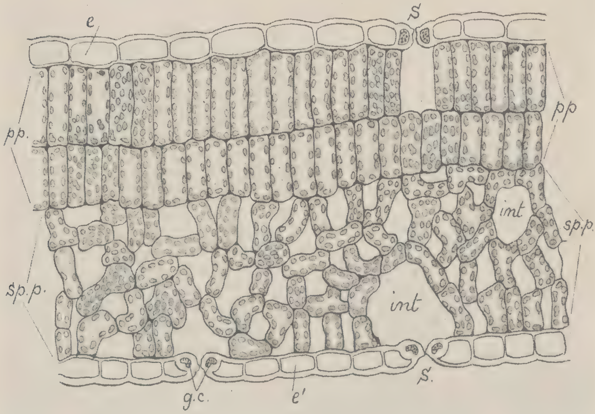


FIG. 41.—SUNFLOWER LEAF, TRANSVERSE SECTION OF BLADE. (High power.)

e, upper epidermis ; *s*, stomate ; *int*, intercellular spaces ; *p.p*, palisade parenchyma with chlorophyll ; *sp.p*, spongy parenchyma ; *e'*, lower epidermis ; *g.c*, guard cells.

The section is bounded on each side by a row of epidermal cells with a thin cuticle (Lat. *cutis*, skin). Stomata are present in both the upper and the lower epidermis, but are more numerous in the latter. Many mesophytic leaves have no stomata on the upper surface; the rapid withering of the sunflower is partly due to the stomata on both surfaces, for transpiration is thus necessarily increased. The greater part of the section consists of cells with thin walls and abundant chlorophyll; the two rows nearest the epidermis consist of elongated cells, and form what is called the *palisade parenchyma*, for the cells are packed closely together without any spaces, whereas the parenchyma of the under surface has intercellular spaces; consequently the under side of the leaf is paler than the upper, for there is less chlorophyll, owing to the fact that the cells are not so closely packed. The parenchyma nearest the under surface of the leaf has intercellular spaces, with which the stomata communicate; this is called *spongy parenchyma* to distinguish it from the palisade tissue of the upper surface. The veins, or fibro-vascular bundles, form a network in the parenchyma; the wood of each bundle lies towards the upper surface, the bast towards the lower.

This leaf by its structure is well adapted for assimilation, and allows of considerable transpiration. The thinness of the mesophytic leaf is a constant feature, for if the leaf were not thin some of the cells would be inaccessible by light, and would therefore not be able to assimilate. The thinness of the cuticle is another important characteristic, for on that largely depends the degree to which transpiration is possible.

Structure of Xerophytic Leaf.

With the leaf of the Sunflower may be compared that of a Xerophyte, such as that of a grass growing on sandy seashores, therefore in a dry situation. When the air is moist the blade of the leaf is spread out, with its upper surface flat, or nearly so; but when the air is dry, owing either to a scorching sun or high wind, the leaves fold or roll up, so that the lower surfaces are alone exposed. The rolling up is so complete that at first sight one hardly realizes it is the leaf-blade which is so infolded—the appearance is rather that of a stem or stalk.

The examination of a transverse section of the leaf-blade shows that this infolding is due to some of the upper epidermal cells, which are large and very thin-walled, and when full of sap are distended; but as they lose water by transpiration they contract, and thus draw together the halves of the blade, causing the upper surfaces to become infolded. The stomata are mostly on the upper surface and are situated in grooves, so that the leaf is thus protected from too rapid transpiration; the lower surface, which alone is exposed, is protected from drought by bands of sclerenchyma beneath the epidermis. All these characteristic structures—the thick cuticle, the deep-seated stomata, the infolding of the upper surface on which the stomata are, the presence of sclerenchyma—are protections against too rapid transpiration. There is yet another provision against drought: some succulent leaves, such as those of Aloe, have a layer of cells between the epidermis and the palisade parenchyma, without chlorophyll, and containing instead much watery sap. This "aqueous

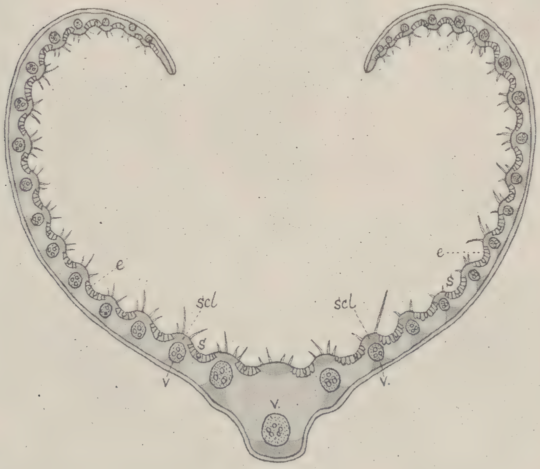


Fig. 42.—Leaf of Xerophytic Grass, Transverse Section of Blade. (Low power.)

e, upper epidermis; *s*, position of stomata; *scl*, sclerenchyma; *v*, fibro-vascular bundles.

tissue," as it is called, has a double function: it acts as a water reservoir, and it protects the chlorophyll of the palisade parenchyma from too great exposure to light. It is interesting to notice that the position of the chlorophyll corpuscles in the cells varies with the intensity of light. When exposed to diffuse daylight, the corpuscles are found on the upper and lower walls of the palisade cells; but if diffuse daylight is replaced by strong sunlight, the corpuscles are removed to the lateral walls and towards the inner end of the cell.

The numerous contrivances against too rapid transpiration may now be summed up:

1. The cuticle, which is thin in a Mesophyte, is always thick in a Xerophyte. Holly is a good instance of this. The thickness of the cuticle is due to the development of a substance called cutin, owing to which the cell-wall becomes less and less permeable to water. A very thick cuticle is always found on trees where the leaves remain several years on the branches, such as Holly, Oleander, Mistletoe, Cactus.

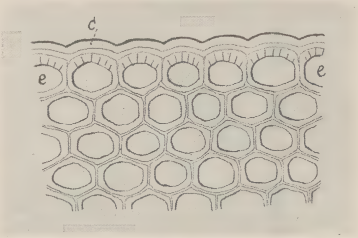


Fig. 43.—Leaf of Holly, Section of Upper Side of Blade. (High power.) *e*, epidermis; *c*, cuticle.

2. Some plants, especially those which grow on steppes and prairies, develop a waxy covering in the cell-walls of the epidermis. This may be seen in young Cherry, Apricot, and Peach trees, where the young leaves are thus protected; but as soon as they burst from the bud, and the cuticle is fully developed, it disappears, so that transpiration may not be hindered.

3. Many plants have a hairy covering on the upper side of the leaf. This is especially the case in alpine plants, which are exposed to dry air only for a few hours each day, and to frost and cold at night. They require to be able to lessen transpiration, owing to the difficulty of getting water in the soil in which they grow. Thus, the Edelweiss has a

layer of woolly hairs, so that the leaf seems almost wrapped in flannel. The same contrivance is found in shore plants which are exposed to burning suns, and have the same difficulty as alpine plants in getting a regular supply of water. An example of this is the Hairy Hawkweed (*Hieracium pilosella*), so widely distributed on the shores of the Mediterranean, and common in England. The leaves of this Hawkweed are radical, and form a rosette, clasping the soil; they are green on the upper side and white on the under, owing to the star-shaped hairs, which form a thick felt on its surface. When the ground gets very dry the leaves turn up, the whole leaf becomes rolled; the under side is then turned towards the sun's rays, and protected by the hairs. One of the most conspicuous of hairy plants in England is the Mullein. It is impossible here to mention all the different kinds of hairs; their variety is immense, and those interested in the subject may consult Kerner (vol. i., pp. 314-325), where some beautiful illustrations are given.

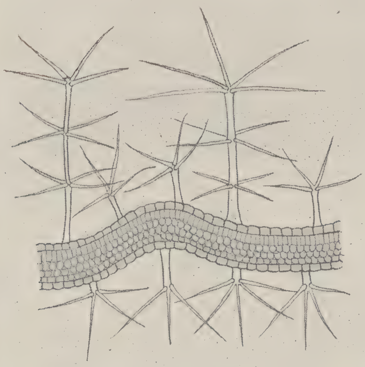


FIG. 44.—SECTION THROUGH LEAF-BLADE OF MULLEIN, SHOWING HAIRS.

Structure of Hydrophytic Leaf.

The leaves of Water-Plants are classified by Willis ("Flowering Plants and Ferns," vol. i., p. 171) as follows:

1. The ribbon type, as in Vallisneria.
2. The much-divided type—*e.g.*, submerged leaves of the Water Crowfoot.
3. The awl-shaped type in submerged leaves, as in Isoetes and others able also to live on dry land.

4. The floating type.

On the whole, the structure of the floating leaf approximates to that of Mesophytes, for the upper surface has a cuticle, which is often waxy; the palisade tissue and stomata are also present. Speaking generally, the leaves of Water-Plants have no protection against too rapid transpiration. They have enormous intercellular spaces full of air, and the leaf-stalks often act as floats.

Leaves that are entirely submerged have no cuticle and no stomata, for they never transpire; they take in water from their whole surface.

It has been shown how the minute structure of the leaf enables the plant to adapt itself to the different conditions of life which obtain in various regions. It may now be considered how the form of the leaf as a whole, and its arrangement on the stem, are connected with the habitat of the plant.

Influence of Light on Form and Arrangement of Leaves.

The physical factor which more than any other determines the form and general arrangement of the leaf is light. To estimate this, the leaves of tropical plants may be compared with those of temperate regions.

1. Tropical plants, speaking very generally, have leaves standing straight up, so that the light falls on the edge, not on the surface, of the blade. This is seen in the Acacia (Plate V., Frontispiece). In this way tropical plants protect themselves from the intensity of the light. On the other hand, in temperate climates, especially where the summers are short and often wet, plants want as much light as they can get. They spread out their leaves in such a way that the surface of the blade shall be as much exposed to light as possible, and the arrangement of the leaves on the stem is such that one does not shield the light from another.

2. The leaves of tropical plants are often linear, and small, as in the Oleander, Eucalyptus, whilst those of temperate regions are big and broad. Tropical plants often have folded leaves, as in the Grasses and Palms, whilst those of plants of temperate regions are flat and smooth. Some tropical plants have leaves arranged in rosettes; being thus

crowded together, free access of air is lessened and transpiration reduced—*e.g.*, Aloe.

The effect of light is also well seen by comparing the leaves of the same species grown under different conditions. The structure of a beech-leaf taken from a tree growing in strong light is, when examined under the microscope, seen to be different from that of a leaf taken from a beech-tree growing in the shade. The palisade parenchyma, in the former case, is far more developed, and has more chlorophyll. Warming has classified certain trees, according to the light they require, as follows:

1. Larch, birch, aspen, alder, require the most light.
2. Scotch fir, ash, oak, elm, maple, come next.
3. *Pinus montana*, spruce fir, lime, hornbeam, beech, require least.

The development of branches of trees very largely depends on how closely the trees are planted, for this affects the amount of light that can reach them. In the Scotch Highlands, where the Scotch fir abounds, there are no branches on the lower part of the trunks of these trees, for enough light does not penetrate, owing to the trees being very thick together. This also affects the undergrowth. As has already been remarked (p. 29), in beech-woods, where the trees are thick there is hardly any undergrowth beyond saprophytic plants; whereas in woods where the trees are less thick, and more light penetrates, the undergrowth is considerable.

TABLE OF COMPARISON OF LEAF STRUCTURES.

MESOPHYTES.	XEROPHYTES.	HYDROPHYTES (submerged).
1. Thin cuticle.	Thick cuticle; also layer of hairs of wax for prevention of transpiration.	No cuticle.
2. Numerous stomata, on one or both surfaces, chiefly on the lower.	Stomata deep-seated.	No stomata.
3. Transpiration constant.	Transpiration often considerably lessened.	No transpiration.

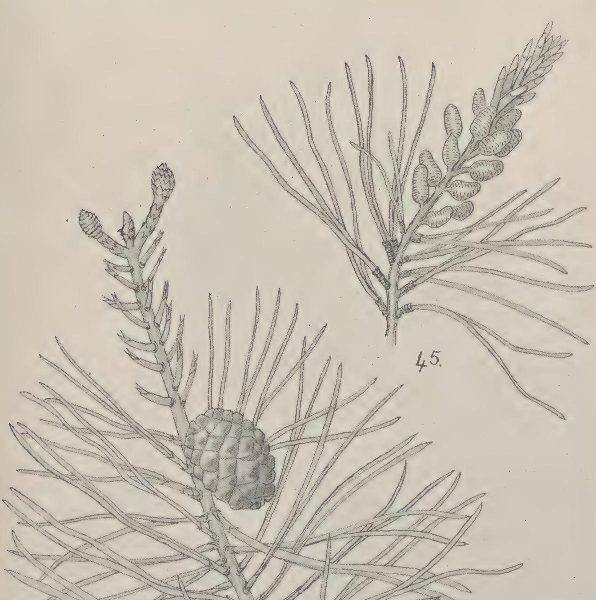


PLATE IV.

Fig. 45.—Branch of Pinus bearing Staminate Cones.
Fig. 46.—Branch of Pinus bearing Carpellary Cones.

CHAPTER X

THE FLOWER

Flower of Gymnosperms.

THE structure of the flower is best studied first in the Scotch Fir (Pinus), a Gymnosperm, for the conditions are simpler than in Angiosperms. Plate IV. shows the staminate and carpellary cones, which occur on the same tree but on different branches. Fig. 45 is a drawing of the branch bearing the staminate cones. It will be seen that the uppermost leaves of the branch are ordinary foliage leaves, needle-shaped, and occurring two together on dwarf shoots, which are spirally arranged. The cones are also arranged spirally at the base of the present year's shoot. Each staminate flower or cone consists of numerous stamens, arranged spirally on a short central axis. The quantity of pollen formed is considerable, as is easily seen in June by shaking the tree, when clouds of yellow dust will fall. Pollination is effected by the wind.

Fig. 46 shows the carpellary flowers, consisting of sessile, conical cones. In the figure, cones of three different ages are represented; these may also be seen in the month of June. They are:

1. Small reddish cones at the apex of the shoot of the current year.

2. Green succulent cones near the apex of the shoot of the previous year.

3. Brown woody cones near the apex of the two-year-old shoot.

Each cone consists of thick scales arranged spirally on a short thick axis. In the youngest cones the scales are not tightly pressed together, and allow of the pollen falling between, for pollination takes place in the first year. The scales of the green succulent cones fit tightly over each other, so that not a drop of rain can get in; it is in these cones that fertilisation takes place. As the cone ripens and the scales become woody they separate, bending outwards, and it is then possible to see two delicate winglike membranes inside. These are the wings attached to the seeds, which, if the cones are sufficiently open, can be taken out with a knife. In the hard old cones, which may be seen on the tree in winter, the seeds have fallen out.

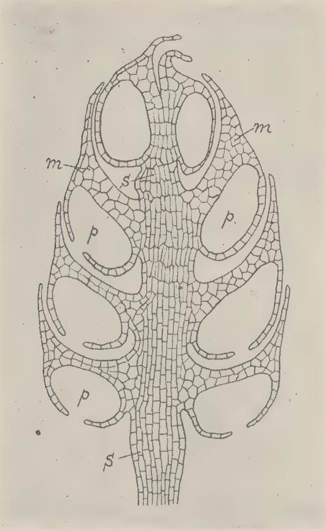


FIG. 47.—STAMINATE CONE OF PINUS, MEDIAN SECTION. (Low power.)
s, stem; *m*, microsporophylls; *p*, microsporangia.

Structure of Staminate Flower. In order to see the structure of the staminate flower, a median longitudinal section should be made; such a section is represented diagrammatically in Fig. 47. It consists of (1) a stem; (2) a number of staminal leaves, or microsporophylls, borne on the stem.

With needles, a single staminal leaf should be detached and examined under the microscope. It shows two parts: a short stalk, or filament, and an expanded anther with two pollen-sacs on the under surface. The anther drawn in Fig. 48 is dehiscing to let out the pollen.

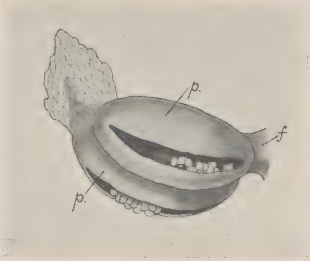


FIG. 48.—A SINGLE STAMINAL LEAF OF PINUS.
f, filament; *p*, pollen sacs dehiscing.

The pollen-sacs, or microsporangia, contain the pollen grains or microspores. Each pollen grain has—

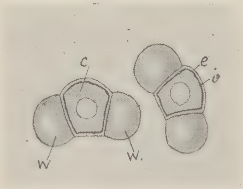


Fig. 49.—Pollen Grains, Pinus.

e, extine; *i*, intine; *c*, central body; *w*, wings.

(*a*) An outer coat, the extine, which gives rise to two large lateral outgrowths, called "wings"; these are air-chambers, which make the pollen grains light, enabling them to be carried by the wind.

(*b*) An inner coat, the intine.

(*c*) The central body, consisting of protoplasm and nucleus; a pollen grain is thus a cell with the essential structure of a unicellular plant. By the time the pollen grains are fully formed the scales of the cone are widely separated from one another, so that the pollen grains fall in between the scales.

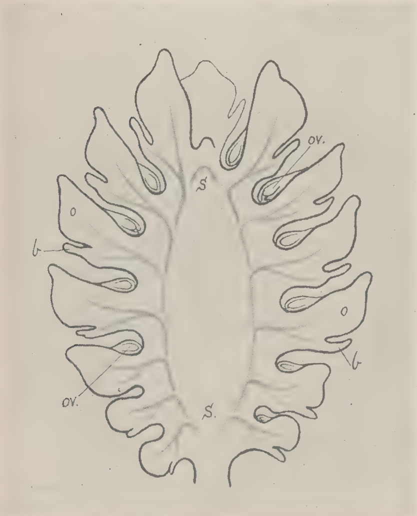


Fig. 50.—Carpellary Cone of Pinus, Median Section. (Low power.)

s, stem; *b*, scaly bracts; *o*, ovuliferous scales; *ov*, ovule.

Fig. 50 represents, to a certain extent diagrammatically, a median longitudinal section of a young cone. It consists of (i.) a stem; (ii.) scales borne by the stem. These scales are of two kinds — brown scaly bracts, and, secondly, scales bearing ovules. These ovuliferous scales are developed on the upper surface of the bract scales, and bear on their upper surface two ovules or macrosporangia. The illustration shows ovules at different stages of development.

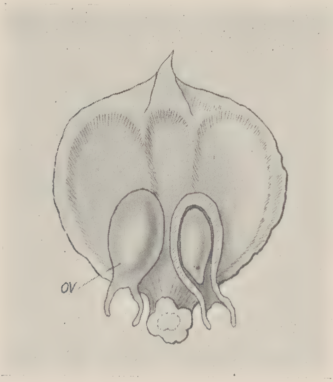


Fig. 51.—A Single Placental Scale with Two Ovules.

In the right-hand one the integument is removed.

A section of an ovule shows—

(i.) One integument, with the micropyle, which is turned towards the stem.

(ii.) A nucellus.

(iii.) An embryo-sac or macrospore, a large cell near the centre of the nucellus.

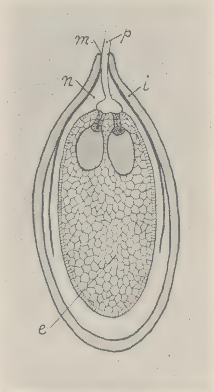


Fig. 52.—Ovule of Pinus; Median Section. (High power.)

i, integument; *n*, nucellus; *e*, embryo-sac; *m*, micropyle; *p*, pollen-tube.

It will be seen that there is only one integument, and it is thought that the scale bearing the ovule answers to the second or external integument which is present in Angiosperms. When the pollen grain falls to the bottom of the scale, it is sucked up by the micropyle owing to the drying up of the mucilage in the micropyle, so that the pollen grain now rests on the nucellus; then it puts out the pollen-tube, the growth of which is soon arrested. As soon as this has taken place, the endosperm begins to be formed; the cells of the nucellus divide, giving rise to a regular tissue, which almost fills the ovule. At the apex of this tissue, or endosperm, one or more egg-cells, or oospheres, are seen. All this takes some months and precedes fertilisation, which does not occur till the year after pollination. Fertilisation is the union of a portion of the pollen grain with the oosphere; the result of fertilisation is that the oosphere is converted into an oospore, from which the embryo arises. The embryo will be found developed in the second year's cones, the large green succulent ones; whilst a third year's cone will contain the ripe seeds, which will show the following parts:

1. A testa developed from the single integument of the ovule;
2. The endosperm enclosing the embryo;
3. The embryo consisting of radicle, plumule, and cotyledons.

From the embryo the root and shoot arise.

In comparing the flowers of Angiosperms with those of Gymnosperms, the essential difference to note is this: In Gymnosperms the macrosporophylls are flat and open, so that the ovules (macrosporangia) are exposed; whilst in Angiosperms the macrosporophylls (carpels) are joined up, and the ovules are in a closed chamber, the ovary.

Stamens of Angiosperms. The stamens, as in the Gymnosperms, contain the pollen grains, but there are four pollen-sacs instead of two, as in Pinus. When fully developed the wall of an anther shows an external epidermis with a well-marked cuticle, and within this a layer of cells with fibrous thickening. At a certain point in the wall, opposite the partition between the two pollen-sacs, the cells are smaller and the thickening is absent; this is the point of dehiscence of the anther. When the anther is ready to dehisce, the partition between the two pollen-sacs of each anther-lobe breaks down at this point of dehiscence, and thus the wall is ruptured. Dehiscence generally takes place by a longitudinal slit, sometimes by a transverse slit or by pores.

Ovule of Angiosperms. The structure of the ovule of an Angiosperm is very similar to that already described in Pinus, except that the integuments are usually two, and that the embryo-sac formed in the nucellus is not filled with tissue, but shows the following structure under a high power of the microscope:

(i.) A large nucleus in the centre.

(ii.) A group of three cells near the micropyle, the lowest of which is the oosphere; the upper two help to direct the pollen tube to the oosphere.

(iii.) At the opposite end of the embryo-sac is another group of three cells, called the antipodal cells. Their function is doubtful. The three upper cells of the embryo-sac are naked cells—the antipodal cells have cell-walls.

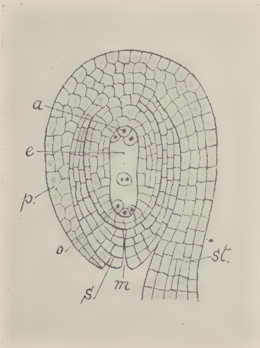
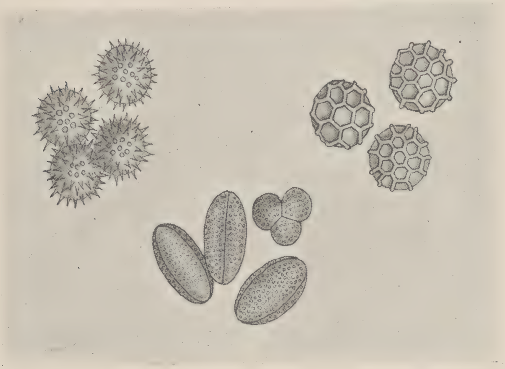


Fig. 53.—Ovule of an Angiosperm, Median Section. (High power.)

p, outer integument; *s*, inner integument; *m*, micropyle; *e*, embryo-sac; *a*, antipodal cells; *n*, nucleus; *o*, oosphere; *st*, stalk.

In Angiosperms the pollen grains are placed on the stigma, and pollen tubes are put out from the grain; they make their way through the loose tissue of the style and enter the ovule by the micropyle. Then fertilisation takes place; after that, endosperm is formed by division of the cells of the nucellus, and the whole of this may be absorbed during the ripening of the seed by the embryo, giving rise to an exalbuminous seed. When the endosperm is not absorbed till germination, the seed is albuminous ("Elementary Botany," p. 58).

Pollen Grains of Mesophytes and Hydrophytes. There is considerable difference in the structure of the pollen grains of those Hydrophytes which are pollinated under water and those which are pollinated above the surface of the water. In pollen grains adapted for pollination in air, the wall consists usually of two layers—the outer, called the extine, and the inner layer, or intine. The extine is usually rough or uneven, so that the grains may easily stick on to the stigma. In those Hydrophytes, however, which are pollinated under water, such as the Grass-wracks (*Zostera*), the pollen grain has no outer coat. As soon as the anthers dehisce, the pollen grains take the form of long cylindrical tubes, and are carried by the flowing water to the thread-like stigmas of the flower. These Grass-wracks are entirely submerged water-plants, abundant in the lagoons around Venice. Many Hydrophytes —in fact, the majority—discharge their pollen above the surface of the water. In this case the pollen grains, as in Mesophytes, have the usual external coat, and are round or elliptical, not cylindrical or tube-like. They are conveyed, not by flowing water, but by wind or insects. Under these circumstances the pollen is dust-like, the grains being separate from each other. In a few cases pollen grains occur in sticky masses in both Hydrophytes and Mesophytes, as in Vallisneria and the Orchidaceæ (Fig. 133). The pollen grains of water-plants must be of the same specific gravity as the water, otherwise they would float or sink.



FIGS. 54-56.—POLLEN GRAINS OF ANGIOSPERMS.

In Mesophytes the pollen grains vary very much in size, in shape, and in the structure of the outer coat; thus, in the Boraginaceæ the pollen grains are small, in Malvaceæ and in Geraniaceæ large, and in those flowers which remain open but a single day or night the pollen grains are especially big, in order to give more chance of their remaining firmly on the stigma. As regards shape, pollen grains are generally ellipsoidal; the next most common form is the crystalline, or angular; they may be cubical, etc. (Figs. 54-56).

The unevenness of the wall and its delicate markings may be observed in the pollen grains of almost any plant which has dry, dust-like pollen.

Lastly, the delicate contrivances of many flowers for the protection of their pollen from wet should be noticed. It would be interesting to make a series of observations on this adaptation to surroundings. Many flowers, for instance, hang down during the rain and spread themselves out in the sunshine; in some cases pollen is concealed in tubular flowers, and thus protected.

In conclusion, it should be noticed that the adaptations of structure to habitat are not so marked in the flower as they are in the vegetative organs, the root, stem, and, above all, the leaf.

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PART III

NATURAL ORDERS

TABLE OF NATURAL ORDERS GIVEN IN PART III.

- **Angiosperms.**
  - **Dicotyledons.**
    - **Polypetalæ** (*petals free*).
      - Ranunculaceæ, Papaveraceæ, Cruciferæ, Caryophyllaceæ, Malvaceæ, Geraniaceæ — *Flower hypogynous.*
      - Leguminosæ, Rosaceæ — *Flower perigynous.*
      - Umbelliferæ (*flower epigynous*).
    - **Gamopetalæ** (*petals joined*).
      - Caprifoliaceæ, Compositæ — *Flower epigynous.*
      - Primulaceæ, Boraginaceæ, Solanaceæ, Scrophulariaceæ, Labiatæ — *Flower hypogynous*
    - **Apetalæ** (*without petals*).
      - Amentaceæ.
  - **Monocotyledons.**
    - **Petaloidæ**
      - Orchidaceæ, Iridaceæ — *Flower epigynous.*
      - Liliaceæ — *Flower hypogynous.*
    - **Nudifloræ** (*without petals*).
      - Gramineæ (*Flower hypogynous*).

CHAPTER XI

RANUNCULACEÆ

The Helleboreæ. THE simple, regular flowers belonging to this Order have been already described ("Elementary Botany," pp. 76-78); but the Helleboreæ must be especially noticed here. This group includes the Christmas Rose, with its conspicuous white sepals and minute petals modified into nectaries; the green Hellebore (*Helleborus viridis*) found in pastures and thickets and about old walls; and the stinking Hellebore (*H. fœtidus*), which occurs in stony places, chiefly on limestone soil. To this division of the Ranunculaceæ belong also the Globeflower (*Trollius*), with its bright yellow, petaloid sepals, and as many as five to fifteen small petals arranged spirally; the Winter Aconite, also with conspicuous sepals; and the Columbine, with spurred petals. Love-in-the-mist (*Nigella*) has five sepals, and about eight small two-lipped petals, the nectary being under the lower lip; whilst the carpels, usually five in number, are more or less completely united. The fruit is of the nature of a capsule, opening when ripe at the top of the ventral suture. Baneberry (*Actæa*) has petaloid sepals, either no petals or an indifferent number, and only one carpel. The fruit is a berry.

Irregular Flowers of the Order. It is, however, the irregular flowers of the Order—Monkshood and Larkspur—that are especially interesting, for in them the structure of the flower is seen to be closely connected with the visits of certain insects. A Buttercup, by its structure—above all, owing to its exposed honey—invites the visits of several kinds of insects; but only humble-bees can get the honey of the Monkshood and Larkspur, for it is only those insects which have a long enough proboscis. Again, a Buttercup, and the majority of the

Ranunculaceæ, are not only cross-pollinated, but can pollinate themselves in the absence of insect visits. In Monkshood and Larkspur self-pollination is impossible, for the stamens are ripe before the carpels.

Monkshood.

The name Monkshood is due to the conspicuous sepal which arches over the rest of the flower, like a hood. There are altogether five sepals: the posterior, which is the largest; there are two lateral and two anterior, which are much smaller. The corolla consists of four petals; the two posterior ones are furnished with long claws, and are modified into nectaries, which are concealed by the posterior sepal. Only one of these is seen in the figure, which represents half the flower. There are two anterior petals, very minute and sometimes absent. The stamens—as always in the Ranunculaceæ—are numerous, and there are three to five carpels, each bearing several ovules.

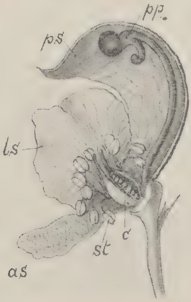

Fig. 57.—Median Vertical Section of Monkshood.

p.s, posterior sepal; *l.s*, lateral sepal; *a.s*, anterior sepal; *p.p*, posterior petal; *st*, stamens; *c*, carpels.

Monkshood is very plentiful in Switzerland; in the month of August it covers the slopes of the Engadine mountains, and, indeed, is distributed throughout the Alps, where Sprengel had abundant opportunity of observing its pollination. He tells us that humble-bees, attracted by the conspicuous dark purple calyx, alight on the lateral sepals, and with their proboscis suck the honey from the nectaries concealed in the hood. Meanwhile the stamens, which ripen before the carpels, are shedding their pollen on to the under surface of the bee's body. When the insect flies away to another flower, if it alights on one in which the stamens are withered, the pollen with which it is covered will be deposited on the stigmas of the carpels that are now standing upright in the path of the bee. Owing to the fact that the carpels are not ripe until after the withering of the stamens, self-pollination is impossible. All this may be observed in old-fashioned gardens, where Monkshood is often planted, especially in the north of England and Scotland.

Larkspur.

Like Monkshood, the calyx of Larkspur is very conspicuous, consisting of five blue sepals that have practically the function of petals, for they attract the humble-bees.

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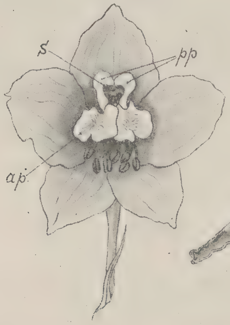

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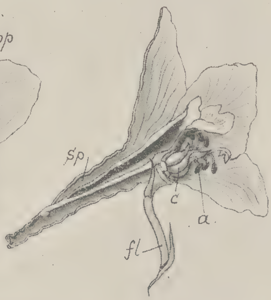

Fig. 58.—Front View of Larkspur.

p.p, posterior petals; *a.p*, anterior petals; *s*, space between posterior and anterior petals with two anthers in it.

Fig. 59.—Side View Median Vertical Section of Larkspur.

s.p, spur of posterior sepal covering spur of petal; *fl*, flower-stalk; *a*, stamens; *c*, carpels.

The posterior sepal, which is spurred, covers the nectaries, its rough and crumpled wall serving as a protection against rain. Into this spur of the calyx fit the spurs of the two posterior petals; it is these that make and hold the honey, which is thus doubly protected; the two anterior petals, with their bundles of upright, yellow hairs, serve as path-finders. The bee, alighting on the flower, presses its proboscis into the space between the posterior and anterior petals, in order to insert it into the spur and procure the honey. If the flower is young, the stamens and carpels are covered by the anterior petals; but as the stamens ripen—and they ripen before the carpels—they raise themselves, so that their anthers lie in the very path of the bee's proboscis, which must thus become dusted with pollen. When the stamens have shed their pollen they wither and lie down; the carpels then in their turn occupy the space formerly occupied by the stamens, and if in this condition the flower is visited by a bee bearing pollen from another flower, cross-pollination takes place.

Larkspur is very common in gardens.

PAPAVERACEÆ.

Type. Field or Corn Poppy (*Papaver Rhœas*). A herb with stiff hairs and milky juice or latex, which circulates in definite channels.

Leaves: alternate, simple, very much divided.

Inflorescence: the flowers are single, large, and terminal.

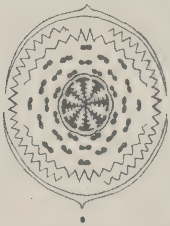

FIG. 60.—FLORAL DIAGRAM OF POPPY.

Calyx: sepals 2, free, inferior, and falling off from the top as soon as the flower opens.

Corolla: petals 4, in two whorls, very much crumpled in bud, and expanding as soon as the calyx drops; free, hypogynous.

Andrœcium: stamens numerous, in several whorls, which alternate with each other.

Gynœcium: carpels indefinite. The ovary is unicellular, but the placentæ project very far into it. The stigmas are sessile, velvety, and stellate.

Fruit: a porous capsule; the pores are close beneath the stigmas at the top of the ovary, so that the fruit seeds only when there is a considerable amount of wind, and the seeds are thrown to a considerable distance. The valves of the fruit alternate with the rays of the stigmas ("Elementary Botany," Fig. 79).

There are several species of poppy ; the two most common in our fields are *Papaver Rhœas* and *Papaver dubium*, the long-headed poppy. This may be recognised by the longer, more oblong, fruit and the stiffer hairs.

Genera.

The Horned Poppy (*Glaucium*) has thick, fleshy leaves, two carpels, which are lateral, and a long thin capsule, which, when ripening, develops a thick spongy replum, that persists after the valves of the fruit have fallen off.

The Greater Celandine (*Chelidonium*) has also two carpels and a fruit very much like that of a wallflower, except that there is no replum, as in the Cruciferæ ("Elementary Botany," p. 62). The milk of this genus is yellow.

The Escholtzia, introduced from California, is now commonly cultivated in our gardens. The flower is perigynous, and has two sepals united to form a cap. The two other genera, the Welsh Poppy and Rœmeria, are not common in England.

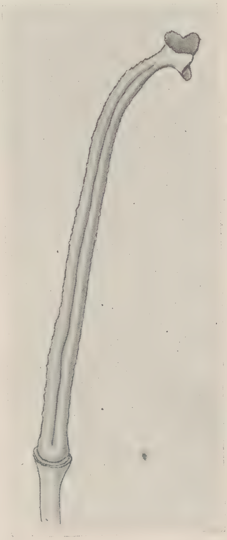

FIG. 61.—FRUIT OF HORNED POPPY.

Characteristics of the Order.

1. The plants are all herbs with latex.
2. The flowers are regular.
3. The calyx consists of 2 sepals, the corolla of 4 petals arranged in 2 whorls.
4. The stamens are numerous.
5. The gynæcium consists of 2 or more carpels, with parietal placentation.

Pollination.

Field Poppies and the Greater Celandine have no honey, but are visited by small insects for the sake of the pollen. In the poppy the anthers, which stand close round the stigmas, dehisce before the flower opens.

Some of the pollen reaches the lower part of the stigmas, so that self-pollination may take place; if, however, insects do visit the flower, they alight on the upper part of the stigmas, and then cross-pollination will occur. In the Greater Celandine cross-pollination depends on the weather; when bright and sunny, the flower opens, and allows of insect-visits; but in dull weather the flower remains closed longer, and insects cannot get inside; consequently the anthers dehisce whilst the flower is still closed, and self-pollination takes place.

Distribution. This Order belongs chiefly to the north temperate zone. Glaucium is common all round the Mediterranean, and in England is found on sandy shores, as its thick fleshy leaves would lead us to expect (p. 11). It is stated that only one species belonging to this Order occurs in the tropics—namely, the Prickly Poppy or the Mexican Argemone.

Medicinal Properties. Many of the plants are of great use medicinally. Opium is procured from the fruit of a species of poppy common in the East; the unripe capsules are opened, the milk flows out and is dried, and from it morphia is prepared. It is on account of its narcotic properties that the poppy represents death in allegorical pictures, such as Rossetti's "Beata Beatrix."

CRUCIFERÆ.

There is not much difference in the various genera belonging to this Order, except in the fruit. It is always easy to recognise a Crucifer, but very difficult in many cases to decide on the genus to which it belongs. To do this not only has the fruit to be carefully examined, but even the seed. The structure of the flower and characteristics of the Order have already been given ("Elementary Botany," p. 79); here it will be sufficient to discuss the fruit.

Chief Types of Fruit. 1. (*a*) The *Silicula*, with a broad replum, as in the Horse Radish, Alyssum, etc.

(*b*) The *Silicula*, with a narrow replum, as in the Penny-cress, Shepherd's Purse ("Elementary Botany," p. 62).

2. The *Siliqua*, as in the Wallflower and Cabbage.

3. The *Lomentaceous Siliqua.*—In this case the fruit is jointed, being divided by transverse partitions into as many segments as there are seeds; it dehisces transversely. This is well seen in the Radish.

The fruit of Sea Rocket (*Cakile maritima*) may be examined in detail. This shows only two joints: the lower one is stalk-like, remains on the plant, and contains one ovule, which, however, does not usually develop into a seed; the upper joint is mitre-shaped, falls off, and contains one seed.

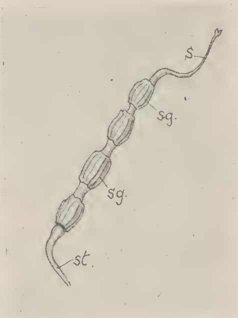

FIG. 62.—JOINTED SILIQUA OF RADISH.

s, style; *s.g*, one-seeded segments; *st*, stalk.

4. *Indehiscent Siliqua.*—Isatis, the Woad of the ancient Britons, has a one-seeded, indehiscent, nut-like fruit, the stalk of which is long, slender, and drooping.

Uses. Many plants belonging to this Order are eaten as vegetables, owing to the fact that in many cases the tap-root by cultivation swells out into the form of a tuber, as in turnips and swedes. It is stated by some botanists that many of the cruciferous plants used as vegetables have

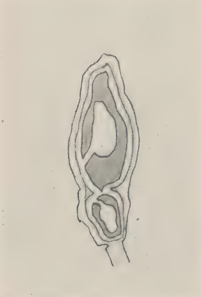

FIG. 63.—FRUIT OF SEA ROCKET.

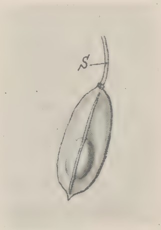

FIG. 64.—FRUIT OF WOAD.

s, stalk.

been derived from halophytic plants, and require a soil comparatively rich in alkalies (Kerner, i. 74). Some cruciferous plants have seeds which yield oil, others seeds used as spices.

CARYOPHYLLACEÆ.

This Order includes two main groups: (1) The *Alsineæ*, represented by Stitchwort, already described ("Elementary Botany," p. 81); (2) the *Sileneæ*, or the Pink and Carnation group, of which the Red Campion may be taken as a type.

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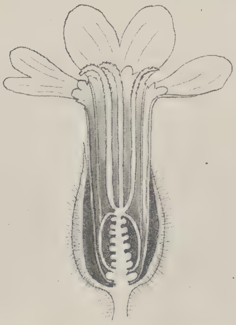

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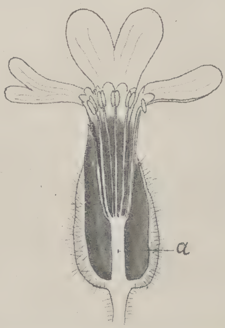


FIG. 65.—MEDIAN VERTICAL SECTION, PISTILLATE FLOWER OF RED CAMPION.

FIG. 66.—MEDIAN VERTICAL SECTION, STAMINATE FLOWER. *a*, internode.

Red Campion (*Lychnis diurna*) is a herb growing in damp places with stems swollen under the nodes and opposite, decussate leaves; its inflorescence is a two-sided cyme.

Flower: sepals 5, joined to form a tubular calyx, which marks off this group of the Caryophyllaceæ from that to which the Stitchwort belongs.

The petals are 5, deeply divided, showing a well-marked division into blade and claw, at the junction of which are appendages, called *ligules.* The internode between the calyx and corolla is of considerable length, and should be noticed

(Fig. 66, *a*), for usually the leaves of a flower are situated in the receptacle one immediately above the other, so that practically there are no internodes. In this species of Lychnis as well as in *Lychnis vespertina* (White Campion), the staminate flowers are on one plant, the pistillate on another. The stamens are in 2 whorls, both of which are always developed in this group, whilst in the Stellaria group the inner whorl of stamens is often wanting. The carpels are 5, styles 5, placentation free central. The fruit is a capsule, dehiscing by 10 teeth.

DIFFERENCES IN THE GROUPS.

ALSINEÆ (STELLARIA).	SILENEÆ (LYCHNIS).
1. Sepals free.	Sepals joined, therefore calyx tubular.
2. Inner whorl of stamens may be wanting.	Both whorls of stamens invariably present.
3. The gynæcium consists of 3 carpels, and therefore the fruit dehisces by 6 teeth.	The number of carpels varies; it is often 5, and the fruit shows 10 teeth.

The *genera* belonging to the *Alsineæ* are often small, creeping plants growing in dry, dusty places by the roadsides; they have small flowers with white petals, as in the Chickweeds (Stellaria) and Sandworts (Arenaria). Sea-Purslane (*Arenaria peploides*) is abundant on shifting sands and sandhills; it has thick, fleshy leaves, with short internodes and a comparatively large fruit. It is one of those sand plants which can stand being covered up by the fine sand blown on it by high winds and yet thrive. The rhizome, as in the case of sand-binders, is long and creeping.

Amongst the *Sileneæ* there is often a reduction of carpels; the Campions (Lychnis) have 5, the Nottingham Catchfly only 3, the Soapwort and the garden Carnation only 2. The number is easily ascertained by counting the styles.

The genus Polycarpon, by some botanists considered a distinct group, differs in some respects from both the Sileneæ and the Alsineæ. The lower leaves are in whorls of 4, not 2; the stamens are 3 to 5; the capsule is 3-valved, and the fruit is so abundant that this characteristic gives its name to the genus—Polycarpon, *i.e.*, many carpels.

Distribution. With regard to the distribution of the Order, it is most abundant in the northern temperate zone; a few species are found in the arctic regions, and still fewer in the tropics. Polycarpon is restricted to the Channel Islands, Cornwall, Devon, and Dorset, and flowers in June and July. The Order is a large one, containing about 1,100 species.

Pollination. This may be studied in the Ragged Robin (*Lychnis floscuculi*). This plant is visited by bees, moths, butterflies, and flies with very long tongues, for, owing to the fact that the calyx is tubular, the honey is less exposed than in the Stellaria ("Elementary Botany," p. 56), so that only small insects which can creep into the tube, or insects with long probosces, can get the honey. The stamens ripen before the gynæcium, the outer ones first, then the inner. When these last have withered the 5 styles grow up exposing their inner surfaces, which, if insect-visits occur, become dusted with pollen from other flowers. This species of Lychnis occupies an intermediate position between those caryophyllaceous flowers which have the honey exposed as in Stellaria, and those in which it is even more concealed than it is in Lychnis. Some of the Caryophyllaceæ—*e.g.*, the Pinks and Soapworts—are visited only by butterflies and moths (Lepidoptera). Those visited by the Lepidoptera that fly in the day usually have bright colours, whilst those that attract the nocturnal Lepidoptera do so by their strong scent and their white flowers which open in the evening, as *Lychnis vespertina*.

MALVACEÆ.

Type. Common Mallow (*Malva sylvestris*).

A biennial herb, with branched stems, clothed with stiff hairs. The leaves have long stalks, they are stipulate, round, consisting of 5 or 7 lobes.

Inflorescence: solitary or consisting of compound cymes.

Flower. *Calyx:* sepals 5, joined, inferior, twisted in the bud. Beneath the calyx are 3 bracts, not joined together and forming an epicalyx.

Corolla: petals 5, free, attached to staminal tube, twisted in the bud.

Andrœcium: stamens 5. We should expect to find 10 stamens as in the Geraniaceæ, but only those opposite the 5 petals are developed; the 5 belonging to the sepals are suppressed. Each stamen is subdivided, each subdivision being provided with only one anther lobe. These 5 stamens unite by their filaments into a tube, and the andrœcium is described as monadelphous.

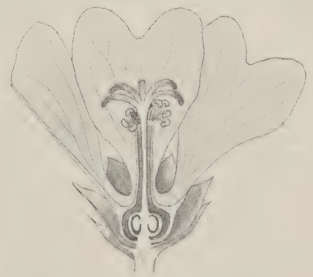


Fig. 67.—Median Vertical Section of Mallow.

Gynœcium: carpels many, joined, superior. There is only one style, but as many stigmas as there are carpels.

Fruit: a schizocarp ("Elementary Botany," p. 64), each fruitlet containing one seed and being indehiscent.

Pollination. Observations should be made on the Dwarf Mallow (*Malva rotundifolia*) and the Common Mallow (*Malva sylvestris*). The former has comparatively inconspicuous flowers, and it will be found that these are seldom visited by insects; there is consequently a special provision for self-pollination; this species has far longer stigmas than the other; they twine in and out amongst the anthers. The Common Mallow, on the other hand, has conspicuous flowers which attract insects; the stigmas are shorter and the stamens are below, so that the plant cannot pollinate

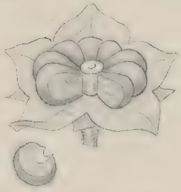
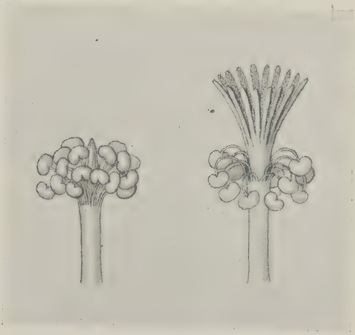


Fig. 68.—Schizocarp of Mallow, One Fruit separating.

itself. The nectaries in this species are situated between the bases of the petals, and are protected from the rain by hairs (Fig. 67). In this species the stamens are ripe before the stigmas, so that cross-pollination is doubly provided for.



Figs. 69, 70.—Gynæcium of Malva Sylvestris in Two Stages.

British Genera. The following are the British genera:

1. The *Tree Mallow*, which has no epicalyx and is found chiefly on the west and south coasts of England and Ireland, growing on rocks.

2. The *Mallows* proper.

3. *Althæa*, the genus to which the garden Hollyhock belongs.

4. *Malope*, a commonly cultivated annual. It has an epicalyx of 3 large, heart-shaped bracteoles, and its gynæcium is different from that of the other genera. The carpels are arranged irregularly in vertical rows, and separate from each other even before they are ripe. The style is divided into as many branches as there are carpels.

Characteristics of the Order. 1. The lobed, stipulate leaves, palmately veined.

2. The regular, hypogynous flowers, with united calyx, petals twisted in the bud, and monadelphous stamens.

Distribution of the Order. This is an extensive Order, consisting of 800 species, most of which are tropical. It may be divided into two main groups, according to the nature of the fruit. In the Mallow group, which includes the chief British genera, the fruit is a *schizocarp;* whilst in many of the tropical plants belonging to this Order, such as the Cotton-plant, the Hibiscus, Silk-cotton trees, the fruit is a *capsule*, dehiscing along the midst of the carpel and containing many seeds ("Elementary Botany," Fig. 94).

It is to this group that the Adansonia, or Baobab-tree, said to attain the age of 5,000 years, belongs; in fact, many of the plants belonging to this group are trees with barrel-shaped stems, enormous flowers, and beautiful petals. The Hibiscus, cultivated in English hothouses, grows wild in the tropics, and is very often planted to form garden hedges. The most common species has beautiful large red flowers.

Uses. The most important plant, from the economic point of view, is the Cotton-plant, calico being manufactured from the hairs of the seeds. In some other plants of the Order, as, for instance, a species of Hibiscus, the bast fibres are strong enough to make hemp. Many other plants are medicinal.

GERANIACEÆ.

Type. MEADOW GERANIUM (*Geranium pratense*). A herb with erect stems and palmately-divided leaves.

Inflorescence: flowers axillary, on long stalks, bluish purple, and large.

Calyx: sepals 5, free, inferior.

Corolla: petals 5, free, hypogynous.

Andrœcium: stamens 5 + 5, free, hypogynous, in 2 rows; the 5 outer are longer, alternating with the petals, and bearing nectaries at their base.

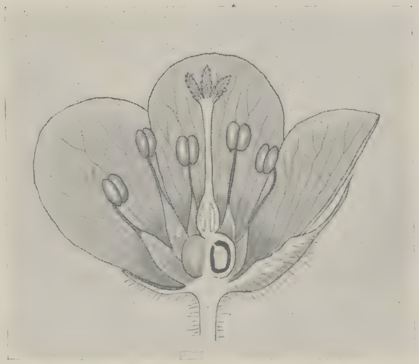
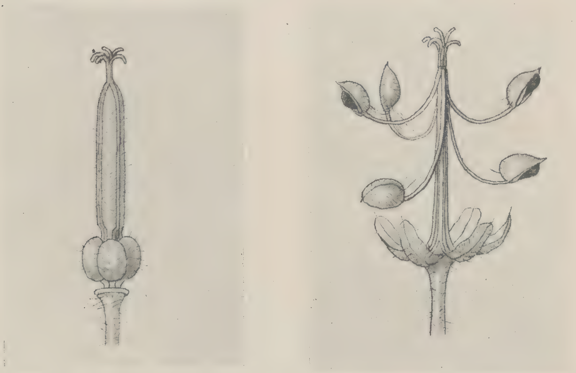


FIG. 71.—MEDIAN VERTICAL SECTION OF GERANIUM PRATENSE.

Gynœcium: carpels 5, joined, superior. The style, generally called the *beak*, separates at its apex into 5 styles, which bear 5 stigmatic surfaces. When ripe, the 5 carpels become detached, and bend or roll back, being spirally twisted and leaving a central column, called the *carpophore*, because it bears the carpels. The fruit is thus a *Schizocarp* ("Elementary Botany," p. 64). In the geranium each carpel, as it rolls back, opens along the edge, shooting out the seed to a considerable distance; each single fruit is thus a capsule. In some genera belonging to the Order the carpels, though separating from each other, do not dehisce; then the fruit, falling on the ground, buries itself by means of its beak, and the seeds do not burst the seed-vessel until ready to germinate.

72 73



FIGS. 72, 73.—GERANIUM SANGUINEUM, SCHIZOCARP BEFORE DEHISCENCE, AND DEHISCING.

Pollination. *Geranium pratense* has lost the power of self-pollination, probably owing to the fact of insect-visits through a long period of time. Other species of geranium are still capable of self-pollination when insect-visits fail; but this is not the case with *Geranium pratense*, owing to the fact that the stamens dehisce before the stigmas are ready to receive pollen. Three stages in the pollination of this geranium may be made out: first, the 5 outer stamens ripen, dehisce, and wither; then the 5 inner stamens dehisce, the stigmas being still immature; lastly, the stigmas spread out their surfaces above the withered stamens ready to receive the pollen brought by the bee. The flower is open by day, hangs down and half closes itself at night.

Genera. 1. *Geranium.*—This genus includes many species; the most common is Herb Robert, easily recognised by the swollen nodes of its stem, its reddish colour, and disagreeable smell when rubbed. *Geranium sanguineum* is one of the most beautiful, with purplish-red flowers; it likes shade, but its deep red colour makes it conspicuous, and it is insect-visited. It is very local, but where found is usually abundant. *Geranium sylvaticum* is found in moist woods and thickets. There are several other species of Geranium, many with very small flowers.

2. The genus *Erodium* is distinguished from most of the geraniums by having pinnate, not palmate, leaves; the stamens are only 5, the inner row being replaced by scale-like structures, called staminodes. The beaks of the fruit twist themselves spirally, but the carpel does not split to send out the seed as in the Geraniums. Common Erodium is mostly found by the sea, and has the creeping character generally found in shore-plants. Some botanists place Wood-sorrel, Balsam, and Nasturtium (*Tropæolum*) in this Order; others group them separately. Wood-sorrel (*Oxalis*) is easily recognised by its leaves, which are compound, consisting of three leaflets arranged digitately. Each leaflet is indented at its apex, and is very sensitive, though not so much so as Mimosa. During the day the three leaflets are spread out; towards evening they sink downwards. These movements may be produced by shaking the flower-pot for some time, by putting the plant in the dark, or by rubbing the under surface of the pulvinus, a little swelling at the base of each leaflet.

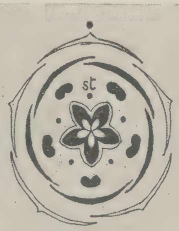


FIG. 74.—FLORAL DIAGRAM OF ERODIUM.

st, staminodes.

Balsam and Nasturtium have irregular flowers. The fruits of the former burst with a loud noise, scattering their seeds to a considerable distance. The garden Pelargoniums also belong to this Order.

Distribution. On the whole, the plants of this Order are most common in moderately warm climates, such as South Africa.

THE LEGUMINOSÆ.

Sub-Orders. The Leguminosæ include three well-marked Sub-Orders.

1. The *Papilionaceæ*, of which the Sweet Pea has been taken as a type ("Elementary Botany," pp. 81-84).

2. The *Mimoseæ*, type Acacia.

3. The *Cæsalpineæ*.—The most widely-distributed genus is Cassia, from one species of which senna is derived. This Sub-Order is almost entirely confined to the tropics; for this reason the type chosen is the Judas-tree, which is cultivated in English gardens.

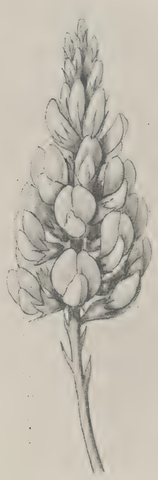


Fig. 75.—Spike of Sainfoin.

Characteristics of Sub-Orders. These Sub-Orders have the following characteristics:

i. The roots, as a rule, have tubercles (Fig. 40), produced, probably, by some bacterium, by means of which the plant is able to take in the free nitrogen of the atmosphere ("Elementary Botany," p. 123).

ii. The leaves are stipulate, and nearly always compound.

iii. The flower is irregular in the Papilionaceæ and Cæsalpineæ, but regular in the Mimoseæ.

iv. The gynæcium invariably consists of one carpel.

v. The fruit is generally a legume, sometimes a lomentum.

Special Structures of Genera. The following special structures of the different genera should be noted. In many of the Papilionaceæ the terminal pairs of leaflets are developed into tendrils, which enable the plant to climb; in one species of Lathyrus, the whole leaf is modified into the tendril, whilst the leaves of some shrubs, such as Gorse, are spinous. Broom has simple, not compound, leaves. In the Scarlet Runner the stem, not the leaf, is the climbing organ.

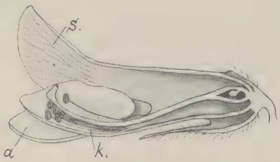


Fig. 76.—Median Vertical Section of Clover.
s, standard; *a*, wings; *k*, keel.

In Clover not only the calyx, but the corolla, persists. The petals are joined and the stamens are partly attached to the corolla-tube. In one species of Clover the fruit ripens underground.

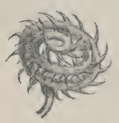


Fig. 77.—Fruit of Medick.

The twisted fruit of Medick should be noted.

In some genera—*e.g.*, Ornithopus—the ovary becomes divided by transverse divisions into as many cells as there are seeds. The fruit is then called a lomentum; it dehisces transversely into nut-like joints.

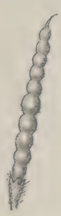


Fig. 78.—Lomentum of Ornithopus.

The fruit of the Sainfoin is a one-seeded nut.

In some cases the calyx becomes bladder-like, developing into an organ of dispersion. Lady's fingers (*Anthyllis*) and a species of Clover (*Trifolium fragiferum*) are instances of this (Fig. 79).

The mode of germination is varied in the Papilionaceæ. In the majority the cotyledons come above ground, develop chlorophyll, and take part in the work of assimilation; but in the Vetches and Peas and some other genera the cotyledons are thick and white, remain in the ground, always enclosed in the testa, so that they take no share in assimilation. In some species of Kidney-Bean they are raised above the ground and become green, but still remain very thick and fleshy.

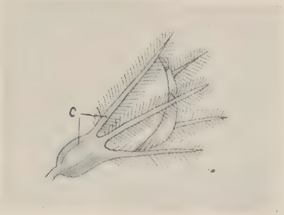


FIG. 79.—FRUIT OF TRIFOLIUM FRAGIFERUM.
c, calyx.

The Mimoseæ. Type: Acacia. The apparent leaves of the Acacia, figured in Plate V. (Frontispiece), are leaf-like petioles without blades, presenting their margin to the light (p. 11). Many Australian species have compound leaves when young, and these blade-like petioles when old.

Inflorescence: the apparent flowers, spherical in form, are inflorescences.

Flower. *Calyx:* sepals 5, joined, inferior.

Corolla: petals 5, free, and in some species, at any rate, perigynous.

Andrœcium: stamens numerous, free.

Gynæcium: carpel 1, superior.

It should be carefully noted that the flower is not papilionaceous, but regular. The *fruit* of the species figured in Plate V. (Frontispiece) is a long pod; in this Sub-Order the fruit is varied; it may be a legume, a lomentum, or a single nut.

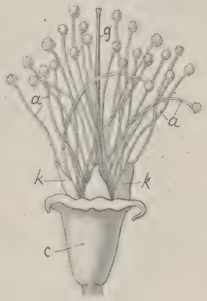


FIG. 81.—SINGLE FLOWER OF ACACIA.
c, calyx; *k*, corolla; *a*, andrœcium; *g*, gynæcium.

The Cæsalpineæ. Type: the Judas-tree (*Cercis siliquastrum*). The *corolla* is irregular, and the petals overlap differently from the Papilionaceæ. The posterior petal (*s*) is the smallest, and is overlapped by the two lateral petals (*a*), they in their turn by the two inner petals, forming the keel (*c*).

The *stamens* are 10, with the filaments free.

The *gynœcium*, as invariably in the Leguminosæ, consists of one carpel.

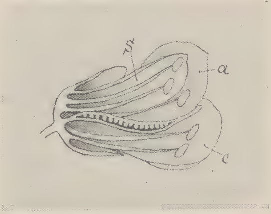


Fig. 82.—Median Vertical Section of Judas-tree.
s, standard; *a*, wings; *c*, keel.

Distribution and Uses. This is a very large and widely distributed Order; there are about 7,000 species belonging to it. The Mimoseæ and the Cæsalpineæ are almost entirely confined to tropical or sub-tropical regions, and although many of the Papilionaceæ belong to the temperate zone, a very large number form the forests of the tropics. The various forms of the leaf—which, as we have seen, is an important organ from the point of view of distribution—the variety in the fruit, and facilities in its dispersion, may partly account for this.

No Order contains more plants useful to man. From some species medicines—namely, senna, quinine, liquorice—are derived; others yield dyes, such as logwood and indigo; many others furnish valuable timber; whilst the peas, beans, lentils, of temperate climates are too well known to need description.

ROSACEÆ.

The following Sub-Orders are arranged according to the form of the receptacle and fruit:

1. *Roseæ.*—The receptacle is concave and persistent round the fruits, which consist of an indefinite number of achenes —*e.g.*, Dog-rose ("Elementary Botany," p. 85).

2. *Spiræeæ.*—The receptacle is flat, the fruits are follicles, from 5 to 10 in number—*e.g.*, Meadow-sweet and Dropwort.

3. *Pruneæ.*—The receptacle is cup-shaped, and drops off, leaving a single carpel, which develops into a drupe—*e.g.*, Plum, Cherry, Blackthorn ("Elementary Botany," p. 84).

4. *Poterieæ.*—The receptacle is concave and dry, persisting

round the fruits, which are one or two in number and are achenes — *e.g.*, Lady's Mantle, Great Burnet, Salad Burnet, Agrimony. Lady's Mantle (*Alchemilla*) has no petals, and an epicalyx as well as calyx. In the Salad Burnet (*Poterium*) the upper flowers are staminate, the long red filaments and yellow anthers rendering them very conspicuous; the lowest flowers are pistillate, whilst the middle ones have both stamens and carpels (Fig. 86). This plant is wind-pollinated; the long styles have brush-like stigmas, which catch the pollen.

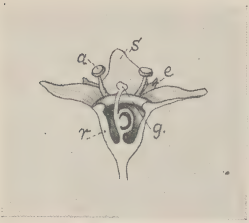


FIG. 83.—MEDIAN VERTICAL SECTION OF LADY'S MANTLE. *e*, epicalyx; *s*, calyx; *a*, anthers; *g*, stigma; *r*, receptacle containing carpels.

The Great Burnet (*Sanguisorba*, Fig. 85) differs from the Salad Burnet in having only 4 stamens instead of an indefinite number, and from Lady's Mantle in the absence of the epicalyx and in the stamens being opposite to, not alternate with, the sepals. There is no corolla in these three genera. The Great Burnet is insect-pollinated.

In Agrimony (Fig. 84), the bristles of the receptacle should be noticed.

5. *Potentilleæ*.—The receptacle is convex, either dry or succulent; the fruits are achenes scattered over the surface of the receptacle—*e.g.*, Cinquefoil, Strawberry, Blackberry, Raspberry, Geum, and Avens ("Elementary Botany," Figs. 88 and 114).

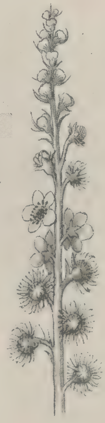


FIG. 84.—SPIKE OF AGRIMONY, SHOWING BUDS AT APEX, FLOWERS IN THE MIDDLE, AND FRUITS AT BASE.

6. *Pomeæ*.—The two to five carpels are enclosed in and

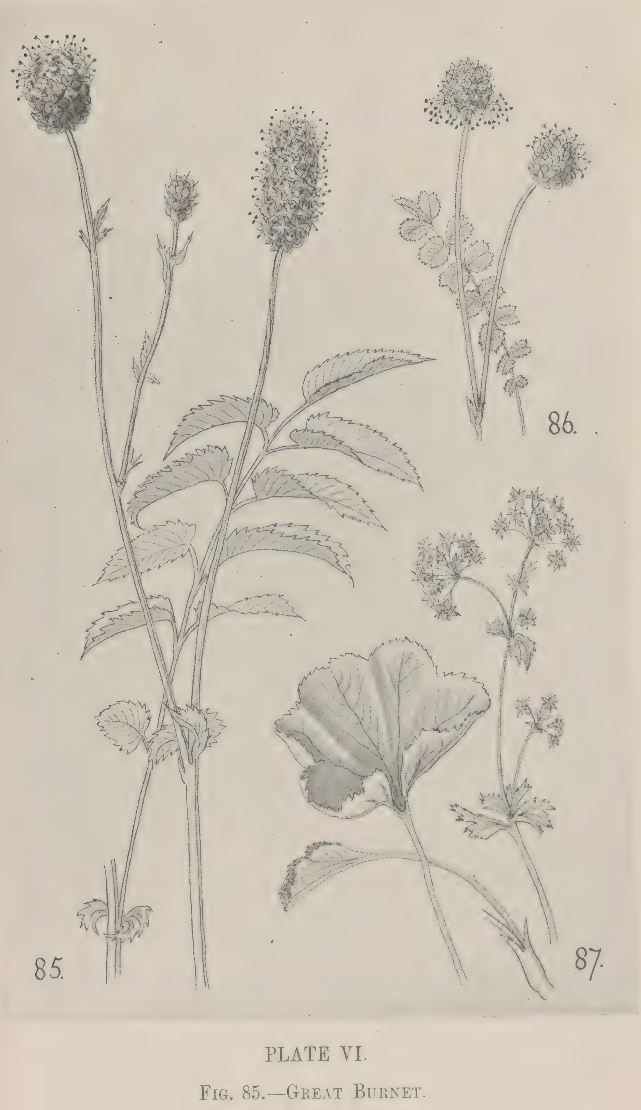


PLATE VI.

FIG. 85.—GREAT BURNET.
FIG. 86.—SALAD BURNET.
FIG. 87.—LADY'S MANTLE.

joined up to the receptacle, which becomes succulent. The fruits may be hard and stony as in the Cotoneaster and Hawthorn, or they may have only a thin wall, as in the Apple, Quince, Pear ("Elementary Botany," Figs. 84, 85, 116).

Pollination of the Order. The pollination of the Rosaceæ is interesting. Many species—as, for instance, the Wild Rose, Agrimony, Meadowsweet have no honey, but are, nevertheless, visited by insects, such as flies and bees, for the sake of the pollen. When honey is present it is secreted by the inner wall of the receptacle. In those species visited by insects cross-pollination is often insured by the gynæcium developing first, as in the Blackthorn, Hawthorn, Pear, Apple, Mountain Ash. In some cases the flowers come out before the leaves, and are therefore very conspicuous. The colour of the flowers varies from yellow to red, but throughout the whole Order there is not a single blue or violet flower, though one or two species which are visited by carrion flies are purple. As a rule those visited by short-lipped insects are greenish, yellow, or white; those adapted for visits by long-tongued insects are in part red; those visited for the sake of the pollen have white flowers if the insect visitors are small, whilst those visited by bees are red.

Affinity of the Rosaceæ with the Leguminosæ. The Rosaceæ and the Leguminosæ approach each other through the Sub-Orders, the Pruneæ and the Mimoseæ. The single carpel of the Pruneæ is a feature in common with the Leguminosæ, which never have more than one carpel; at the same time, it must be remembered that the fruit of Prunus is a drupe, whilst that of the Leguminosæ is usually a legume. The stamens of the Mimoseæ are, as those of the Rosaceæ, indefinite.

Ecology. The habit of the Rosaceæ is very varied. In many cases the shrubby undergrowth of woods is composed of rosaceous plants, such as Brambles, Raspberry bushes, Hawthorn, Blackthorn, Rowan or Mountain Ash.

Some species are xerophilous in character, and are found on mountains or high moors—for instance, Mountain Avens and

Alpine Lady's Mantle; this last is common in the Scotch Highlands, and may easily be distinguished from the common Lady's Mantle by the cut-up leaves and silvery hairs which cover the stems and under side of the leaves. This hairiness is a characteristic of Xerophytes (p. 10). The leaves of Mountain Avens are also white and downy. Silver-grass (*Potentilla anserina*) is also covered with silky down, for it frequents roadsides and stony pastures.

Some of the Rosaceæ, many of the Potentillas, and Agrimony, are characteristic features in meadow vegetation; whilst some few—namely, Water Avens and Marsh Potentil—are aquatic in character.

THE UMBELLIFERÆ.

The general characteristics of the Umbelliferæ have already been described ("Elementary Botany," pp. 87, 88); it will therefore be sufficient here to discuss the differences in a few of the more peculiar genera. The slight differences which exist in the genera are based chiefly on the structure of the fruit, and it is often impossible to identify a species without a careful examination of the fruit.

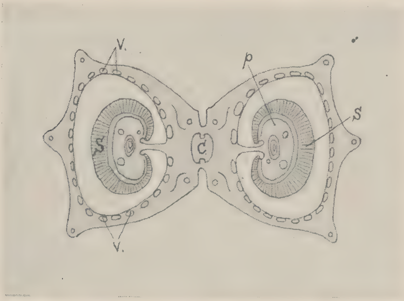


Fig. 88.—Transverse Section of Fruit of Umbelliferæ.
c, carpophore; *p*, placenta; *s*, seed; *v*, vittæ.

Structure of Fruit. The fruit is a *schizocarp* and consists of 2 *mericarps*, each being formed from one carpel and borne by a thin stalk, which is a continuation of the flower-stalk; this is the *carpophore*. It will be seen that the wall of each mericarp projects into well-marked ridges; 5 is the usual number. These are called the *primary ridges* to distinguish them from a second set of ridges, occurring in many genera between the primary, and known as *secondary*. Oil canals, or *vittæ*, are found within the secondary ridges. The seed is often united with the wall of the ovary; the embryo is very small, the greater part of the seed being filled with endosperm, which does not contain starch but oil. The shape of the endosperm—as, for instance, whether flat on the ventral side, or concave, or grooved—helps to determine the genus.

In identifying the genera the first essential is to examine the fruit carefully, noting its shape, the number of ridges and oil-ducts, and the shape of the endosperm. Then the form of the umbel, the structure of the calyx and corolla, are taken into consideration, and lastly the involucres; the involucre belonging to the compound umbel is called the general involucre, whilst those beneath the simple umbels are said to be partial; the presence or absence of "general" and "partial" involucres should be noted.

Genera.

Marsh Pennywort (Hydrocotyle) is a water-plant creeping along the wet mud of bogs or lakes or floating in water. Unlike most of the Umbelliferæ, it has entire leaves and minute white flowers in simple, not compound, umbels.

Astrantia has an involucre composed of bracts of a purplish pink colour. The flowers are small, and usually either staminate or pistillate, and the inflorescence apparently consists of simple umbels, which are, however, cymose. This is well seen in Wood Sanicle, where the flowers are on very short stalks, and form clearly two-sided cymes, not an umbel. The fruit of Wood Sanicle is round and covered with hooked bristles, which no doubt aid in its dispersion; there is no carpophore. The leaves are

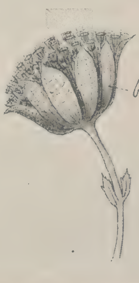


FIG. 89.—FLOWER OF ASTRANTIA. *b*, bracts forming coloured involucre.

palmately lobed, not pinnately divided, as in the majority of the Umbelliferæ. Another Umbellifer, frequent in shady woods, is Sweet Cicely, which has remarkably long fruits. The plant is very fragrant.

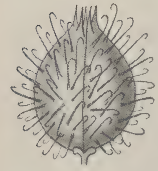


FIG. 90.—FRUIT OF WOOD SANICLE.

The leaves of Sea-Holly are thorny, a xerophytic characteristic (p. 11). The involucre and the bract under each flower are all prickly. The inflorescence of the Sea-Holly is not an umbel, but a cymose head of flowers.

Sea-Samphire has fleshy, succulent, much-divided leaves. Amongst those that are useful for food may be mentioned the Caraway, Fennel, and Pimpinella, which yield seeds that are rich in oil; the roots of the Carrot, Parsnip, and Celery (in this last the internodes also) are eaten as vegetables, whilst several of the Umbelliferæ are useful as medicines.

Pollination. The Umbelliferæ are markedly protandrous—that is to say, the andrœcium develops before the gynæcium. In some cases all the flowers of a whole inflorescence will not protrude their styles and develop their stigmas until after this pollen has been shed.

Variety of Leaf. The variety of leaf-form in this Order is interesting, and shows adaptation to surroundings. Those which grow in hedges—*e.g.*, Hedge-Parsley, Goutweed, Hogweed, etc.—have very divided leaves, so that the plant has every chance of getting light. Shore-plants have succulent or thorny leaves; whilst Bupleurum, which inhabits stony wastes, has narrow, entire leaves, almost reduced to a stalk in some species, probably for the lessening of the transpiring surface. The entire, roundish leaves of Hydrocotyl serve a different purpose—they enable the plant to float. The stalk comes in the middle of the leaf, which is therefore called peltate. The same form of aquatic leaf is met with in aquatic plants of other Orders, as in the Water-Lily.

CAPRIFOLIACEÆ.

Type. HONEYSUCKLE (*Lonicera periclymenum*).

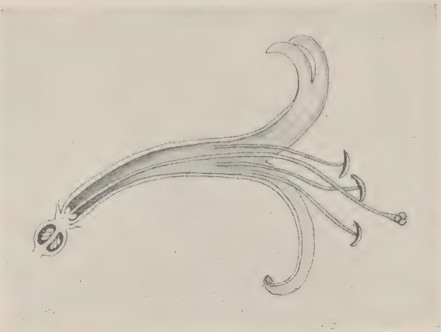


FIG. 91.—MEDIAN VERTICAL SECTION OF HONEYSUCKLE.

A shrub with simple, opposite, exstipulate leaves, climbing to a considerable height by means of its twining stem. In some species of Honeysuckle the leaves unite, so that the stem appears to pass through them (Fig. 94), and the leaves are then described as perfoliate.

Inflorescence: in this species of Honeysuckle the flowers are situated, several together, in heads within each pair of leaves. The flowers are sessile, except those above the last pair of leaves, and these are stalked.

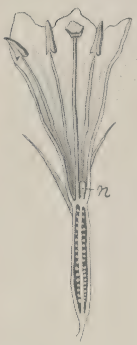


FIG. 92.—MEDIAN VERTICAL SECTION OF WEIGELIA.
n, nectary.

The *flowers* are irregular, almost bilabiate and epigynous.

Calyx: sepals 5, joined, superior.

Corolla: petals 5, joined, epigynous; the tube is long.

Andrœcium: stamens 5, free, epipetalous; anthers versatile.

Gynœcium: carpels 2 or 3, joined, inferior.

Fruit: a small red berry, with 1 or very few seeds.

Honeysuckle is pollinated by long-tongued nocturnal moths, chiefly Hawk moths.

Genera. In the garden shrub Weigelia or Diervilla the very long inferior ovary should be noticed; this looks at first sight like a flower-stalk, but is soon seen to be the gynæcium, consisting of two carpels. The nectary should also be noted (Fig. 92, *n*).

The fruit is a capsule.

Snowberry (*Symphoricarpus*) is easily recognised by the white berries; the ovary is 4-chambered, but only 2 ovules are developed. The flowers of the Snowberry seem specially adapted for wasps: the corolla hangs down; the wasp hangs below the flower, thrusting in its head and licking the honey, secreted by the swelling at the base of the style.

The Elder differs from the Honeysuckle in having pinnately compound and stipulate leaves; the flowers are small and white; the corolla has a very small tube, then the petals spread out, giving it a rotate appearance. The fruit is a berry-like drupe; it contains 8 stones. Self-pollination is more usual than cross-pollination, the pollen falling directly on the stigma in many flowers.

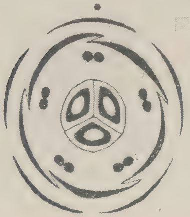


FIG. 93.—FLORAL DIAGRAM OF ELDER.

The Guelder-rose (*Viburnum opulus*) has palmately-lobed leaves; the marginal flowers of the inflorescence are usually barren, having neither stamens nor styles. These flowers are conspicuous, attracting insects, which visit these shrubs far more than they do the Elder.

The Wayfaring-tree (*Viburnum lantana*) is very woolly, the young shoots and leaves being thickly covered with a soft mealy down. This tree is the only British shrub that has its buds unprotected by scales in winter; the flowers are small, but not barren, as in the Guelder-rose.

Linnæa borealis—the one plant which the great Swedish botanist, Linnæus, would consent to have named after him—is a small creeping Alpine plant, found in Scotland and Switzerland, and very occasionally in Yorkshire. It has pink petals and only 4 stamens, the fifth posterior stamen being suppressed.

Some botanists still include the genus Adoxa in this Order,

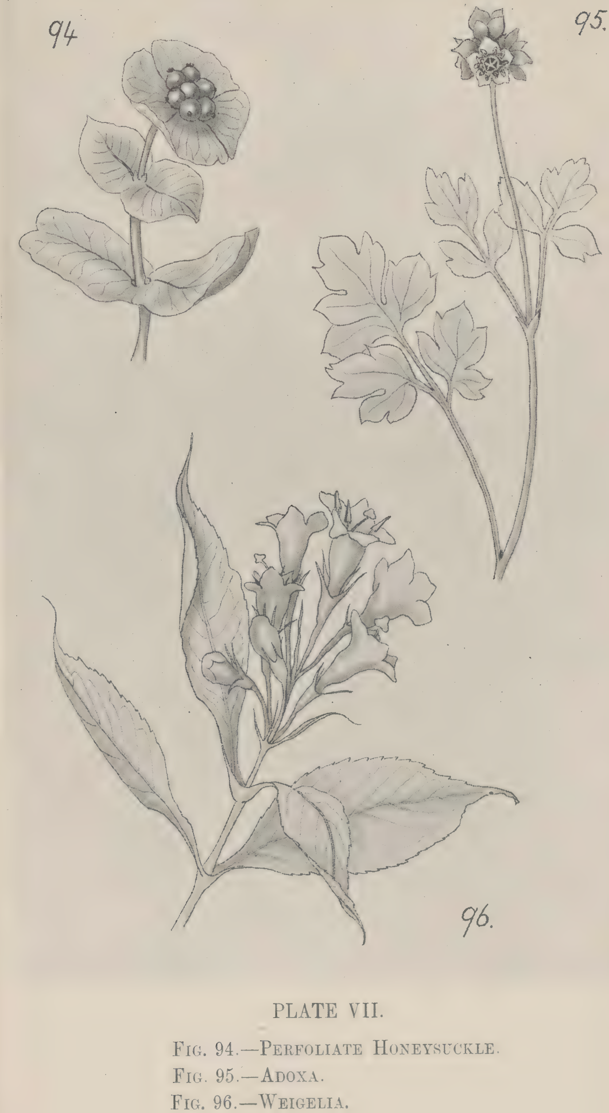


PLATE VII.

Fig. 94.—Perfoliate Honeysuckle.
Fig. 95.—Adoxa.
Fig. 96.—Weigelia.

though others place it in an Order by itself. It is found in damp woods or damp hedges, and flowers early in spring. The flowers are pale green, in globular heads, generally 5 together (Plate VII., Fig. 95).

The number of floral leaves varies; in the terminal flower of each head there are often 2 divisions to the calyx, 4 to the corolla, and 8 stamens; whilst in the lateral flowers the calyx is 3-lobed, the corolla is 5-lobed, and there are 10 stamens.

Characteristics of the Order. 1. With the exception of Adoxa and Linnæa, the plants are shrubs or trees.

2. The leaves are opposite and usually exstipulate.

3. The number of floral leaves is 5, except the carpels, which may be 2 or 3.

4. The flower is epigynous, the ovary being inferior.

Distribution. This is a small Order, containing only about 230 species, belonging chiefly to the northern hemisphere. In this country most of the plants are found in hedges, or are under-shrubs, forming "secondary" species of woods (p. 7).

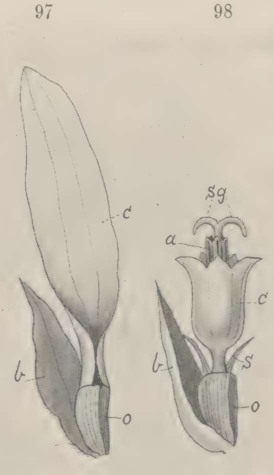
COMPOSITÆ.

The Compositæ include two chief Sub-Orders, the *Tubulifloræ* and the *Ligulatæ*. All the types considered here belong to the former group; the Ligulatæ have been sufficiently given in the "Elementary Botany," p. 89.

Sunflower. The inflorescence of the Sunflower consists of ray florets and disc florets; the former are yellow and very conspicuous, the latter are brown and very numerous. In looking at an inflorescence, it will be noted that the outermost disc florets develop before the inner ones. The receptacle on which all the florets are situated is seen to be slightly convex when all the florets have been removed; the involucre is composed of 3 series of bracts.

The ray florets are situated in the axil of a large bract; the calyx is represented by one to five minute teeth; the corolla consists of 5 petals, completely united, not even toothed, as in many of the allied Compositæ, such as the Ox-eye Daisy. There are no stamens, and no ovules are developed in the ovary, so that the ray florets are merely attractive.

The disc florets also arise in the axil of a bract; the sepals are represented by scales; the corolla is tubular, and consists of 5 petals; the stamens are united by their anthers, and the gynæcium, consisting of 2 carpels, is inferior.



FIGS. 97 AND 98.—RAY AND DISC FLORET OF SUNFLOWER.

b, bract; *s*, sepals; *c*, corolla; *a*, anther-tube; *o*, ovary; *sg*, stigmas.

Cross-pollination is probable, owing to the development of the stamens before the gynæcium. The Jerusalem Artichoke and the Dahlia have much the same structure as the Sunflower.

Groundsel. Groundsel differs from Sunflower in having all the florets tubular. The bracts of the involucre are in two whorls; the leaves are tipped with black, and the outermost row is shorter than the inner one. The receptacle has no scales. The hairy, white pappus is too well known to need description. Cross-pollination seldom occurs, as the flower is inconspicuous; on the other hand, self-pollination takes place regularly, the pollen grains of the anther-tube adhering to the edge of the stigmas as they separate when emerging from the anther-cylinder. That self-pollination takes place is clear, for Groundsel is productive, even in bad weather, when insect-visits are scarce.

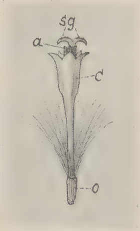


FIG. 99.—FLORET OF GROUNDSEL.

c, corolla; *a*, anther-tube; *o*, ovary; *sg*, stigmas.

This genus is one of the largest of the Compositæ, and very widely distributed.

Cornflower. In *Cornflower* the florets are all tubular; those forming the margin are large, blue, and very conspicuous. They consist only of a corolla, and attract insects. The disc florets are very similar to those of the Sunflower.

Ecology of the Order. About one-tenth of all the Flowering Plants belong to this Order, which is distributed over the whole globe, more particularly in temperate climates; the majority prefer open spaces, and are abundant in meadows. The vegetative organs of the Compositæ vary very much, and this partly accounts for their extensive distribution, as it is

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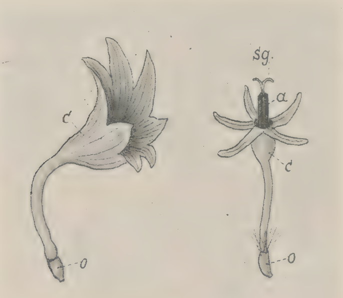


FIGS. 100 AND 101.—RAY AND DISC FLORET OF CORNFLOWER.
c, corolla; *a*, anther-tube; *o*, ovary; *sg*, stigmas.

through the adaptation of these organs that they are able to live in such a variety of habitat. The majority are herbaceous, mesophytic plants. Hydrophytes and Epiphytes are rare ; so, too, are shrubs and trees ; but, curiously enough, these last are plentiful in the Composite flora of oceanic islands.

On the whole the Order is markedly xerophytic in character, as the following genera show.

Sea Aster has fleshy leaves, and grows on the coasts.

Cudweed (Gnaphalium) is an alpine plant, found chiefly in Scotland, and is more or less covered with cottony wool. *Antennaria* is found chiefly on the hills of the seashores, and is also woolly. Many of our Hawkweeds have the hairiness characteristic of xerophytes. One of the most markedly xerophytic plants of the Order is the *Compass plant* (Silphium) of the prairies, which turns the edges of its leaves to north and south, so as to avoid the excessive mid-day sun.

The genus *Senecio* is particularly interesting, for it has plants of the most various habit ; on the whole it is xerophytic. Many species are hairy, and have fleshy leaves. *Senecio viscosus* has leaves capable of inrolling.

The common Daisy (*Bellis perennis*) and the "Weather Thistle of the Alps" (*Carlina acaulis*) show special adaptations for protection from weather. The Daisy closes at night and in wet weather ; whilst in the Thistle the outer bracts are prickly, the inner membranous and shining ; they spread out like a star in dry air, but in damp weather they bend inwards over the flower-head.

PRIMULACEÆ.

Characteristics of the Order.

All the plants belonging to this Order are herbs, and the number of floral leaves is usually 5. The stamens are opposite to, not alternate with, the petals ; this is easily seen in the *Primrose*, but not so easily in the genus *Lysimachia*. The placentation is free central, the fruit is a capsule.

Genera.

The genus *Primula* has already been described ("Elementary Botany," p. 93) ; the following may here be noticed :

Water-Violet (Hottonia), an aquatic plant, with all the leaves submerged, alternately arranged, and very much cut up. The flower-stem arises out of the water, and bears 3 to 5 or 6 pale purple flowers. This plant is found in central and eastern England rather than in the west.

The *Cyclamen* has radical, heart-shaped leaves on long stalks; they are often purple underneath; the flowers are solitary also on long stalks; the lobes of the corolla are bent back over the calyx; the fruit is a capsule. When the capsule is ripe and full of seeds its stalk begins to coil up; it turns downwards, and becomes spirally twisted, so that the capsule is buried in the earth a short distance from the parent plant. In this way the Cyclamen sows its seeds. This may be easily observed by planting Cyclamens on rockeries, when they flower and seed as early as January under favourable circumstances.

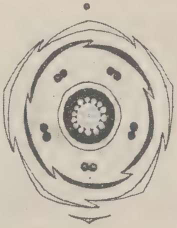


Fig. 102.—Primrose, Floral Diagram.

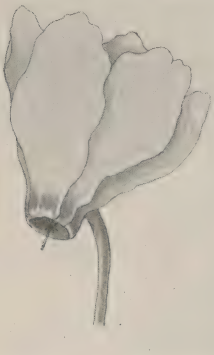


Fig. 103.—Cyclamen.

The wood *Lysimachia* is not unlike the Pimpernel in its manner of growth, but it differs from it in having the yellow flowers characteristic of the genus.

The Creeping Jenny (*Lysimachia nummularia*) has the largest flowers of the genus.

The *Pimpernel*, or Poor Man's Weather Glass (*Anagallis*), is very well known and is found in cornfields. The Bog Pimpernel belongs chiefly to the West of England, and has a very pale pink corolla; in both these the capsule dehisces transversely.

Glaux is an interesting genus consisting of one species. It is a maritime plant, with opposite leaves; it is low and creeping, and only very slightly fleshy. It differs from all the rest of the Primulaceæ in having no corolla; the calyx is, however, petaloid and pink; the stamens alternate with the lobes of the calyx. It is a slender plant, found on sands or in clefts of rocks where the sand has been blown, or in salt marshes.

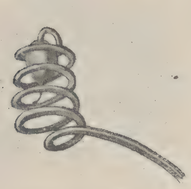


FIG. 104.—FRUIT OF CYCLAMEN.

Trientalis and *Centunculus* (Chaffweed) must be mentioned, because the number of floral leaves is not 5, as in the rest of the Order, but 7 in Trientale and 4 in the Chaffweed. *Brookweed* (Samolus) has an epigynous, not hypogynous, flower, as it has an inferior ovary.

Distribution. On the whole, this Order belongs to the northern hemisphere. Some species are found on specially high mountains: thus, Bird's-eye Primrose (*Primula farinosa*) is found in mountain pastures on all the great mountain ranges of Europe and Asia, even in Greenland and the arctic regions. Cyclamen is alpine, whilst the Wood Lysimachia extends far north into Scandinavia; the Common Trientale, which is very local in the Scotch Highlands, is found in the woods of North Europe, Asia, and America. The species with which we are most familiar in England—viz., the Primrose, Cowslip, Pimpernel—belong respectively to woods, meadows, and cornfields; others, such as the Common Lysimachia, Bog Pimpernel, Water Violet, are semi-aquatic or hydrophytic in habit.

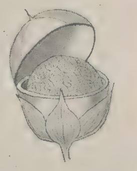


FIG. 105.—CAPSULE OF PIMPERNEL WITH TRANSVERSE DEHISCENCE.

BORAGINACEÆ.

The plants belonging to this Order are herbs, with cylindrical stems and very coarse leaves covered with stiff hairs, so that the plants almost sting. This hairiness is very characteristic of the Order, and is particularly well seen in Viper's Bugloss and Borage. Many of the Boraginaceæ grow in waste places or on roadsides; the hairiness is therefore probably a protection against too rapid transpiration (p. 10).

Classification.

The Order includes two well-marked groups:

(*a*) The Borage group;
(*b*) The Heliotrope group.

The genera belonging to the former group may again be subdivided into:

(i.) Those that have corollas with ligules, as Borage, Comfrey, Hound's-tongue.

(ii.) Those in which the corolla has either no ligules, or very small ones. To this division belong Viper's Bugloss, Lungwort, Gromwell, and others.

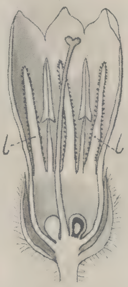


Fig. 106. — Median Vertical Section of Comfrey.
l, ligules.

Description of Comfrey.

A rough, hairy plant, growing, unlike most of the Boraginaceæ, on moist banks. The lower leaves are stalked, the upper ones sessile.

Inflorescence: a cyme, branching on one side only.

Flower: regular and hypogynous.

Calyx: 5-cleft, inferior, hairy.

Corolla: tubular and narrow for half of its length; the tube is closed halfway up by 5 scales or ligules; these protect the honey from being stolen.

Andrœcium: stamens 5, shorter than the petals, epipetalous.

Gynœcium: carpels 2, joined and superior; the ovary is 4-celled, owing to a bending in of the midrib of each carpel;

the style is *gynobasic—i.e.*, it arises from the base of the ovary, between the 4 lobes.

Fruit: a *schizocarp*.

The fruit of the Hound's-tongue, which belongs to the Borage group, should be noticed. It consists of 4 large nuts covered with bristles, which are short, strong, and barbed. These become entangled in the fleece of sheep in thousands, and are thus dispersed. Alkanet and Forget-me-not belong to this subdivision.

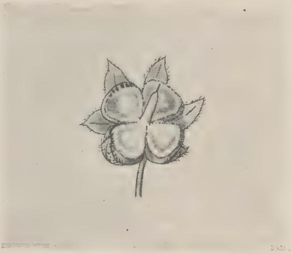


FIG. 107.—FRUIT OF HOUND'S-TONGUE.

Description of Viper's Bugloss.

Viper's Bugloss belongs to the division of the Borage group, which has no ligules on the corolla. This plant exhibits xerophytic characters in a marked degree. It has a long, tapering root; the leaves are rough with coarse hairs. The plant is usually found in dry situations, often on sand-hills, where its blue flowers make it very conspicuous. It should be noticed that the flowers when they first come out are red, and then change to a bright blue. The flower is irregular, the lobes of the corolla being unevenly divided and the stamens unequal in length; there are 2 long ones, 2 shorter, and 1 still shorter.

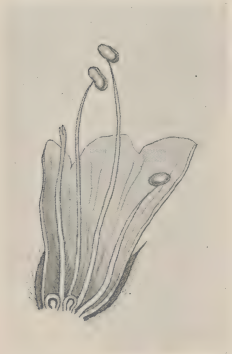


FIG. 108.—MEDIAN VERTICAL SECTION OF VIPER'S BUGLOSS.

Lungwort has 2 forms of flowers, with styles of different lengths. The very hard fruits of Gromwell should be noticed; they are as hard as stone, owing to the formation of lime and silica.

The Heliotrope Group. The chief differences in this group are the undivided ovary, and the terminal, not gynobasic, style.

Pollination and Colour of the Order. The colour of the Boraginaceæ is interesting. Many species undergo changes in colour: thus Forget-me-nots are white, pink, or blue; Viper's Bugloss is red when first opening, then it turns blue. Comfrey also has 3 varieties. Muller thinks that white and yellow were, in some genera at any rate, the primitive colours, and that violet and blue have been preceded by red in many cases. This theory is borne out by the fact that many blue and violet species have white and rose-red varieties. The development of violet and blue colours is probably an adaptation of the flower in relation to the visit of insects. Many different species of insects visit the Boraginaceæ: flies cross-pollinate those with short-tubed corollas; those which have long corollas protect their honey from all except bees, which cross-pollinate Lungwort, Borage, and Alkanet. All these have *blue* flowers. The blue colour probably gradually developed in order to attract bees, which alone had long enough probosces to reach the honey of the long-tubed corolla.

Distribution. There are about 1,150 species, growing mostly in the north temperate zone in dry situations.

SOLANACEÆ.

Type. BITTERSWEET (*Solanum Dulcamara*).

A shrub with alternate leaves, sometimes with two lobes at the base, otherwise simple, with margin entire.

Inflorescence: cymose.

Flower: regular and hypogynous.

Calyx: sepals 5, joined, inferior.

Corolla: petals 5, joined at the base, and forming a short tube; bluish-purple, spreading out, and slightly reflexed.

Andrœcium: stamens 5; the anthers are bright yellow, almost sessile and syngenesious, forming a cone round the style and dehiscing by pores; hypogynous.

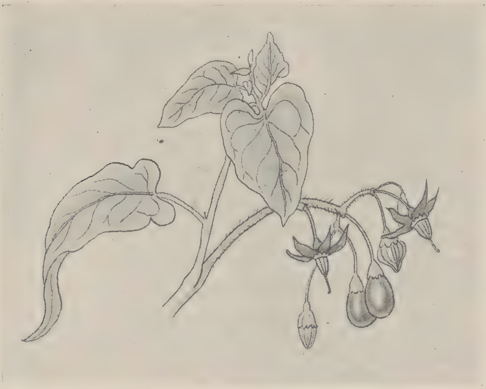


FIG. 109.—WOODY NIGHTSHADE, OR BITTERSWEET.

Gynœcium: carpels 2; oblique, joined and superior; placentation axile.

Fruit: a berry.

This plant is not much visited by insects, for it has no honey and comparatively little pollen. The style, which projects beyond the cone of anthers, curves, so that when the anthers dehisce at their apex some pollen will probably fall on the stigmatic surface, and thus self-pollination may take place in the absence of insect visits.

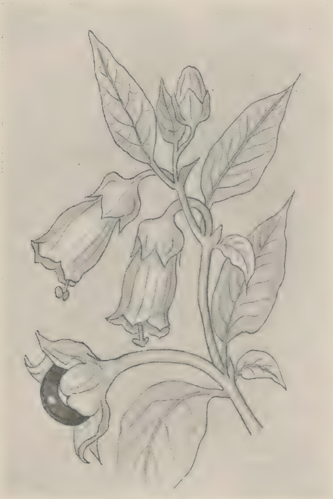


FIG. 110.—BELLADONNA.

The Potato plant belongs to the same genus, Solanum; its propagation by tubers has already been given ("Elementary Botany," p. 22).

Other Genera. *Belladonna* (Atropa) is interesting. The arrangement of the leaves should be noted. They are borne in pairs, a larger and a smaller one together; the larger leaf is the bracteole of the flower; the smaller one is the bract of the flowering shoot, which one would naturally expect to find at the base of the branch; but in this Order the bracts are displaced, being always close under the flower.

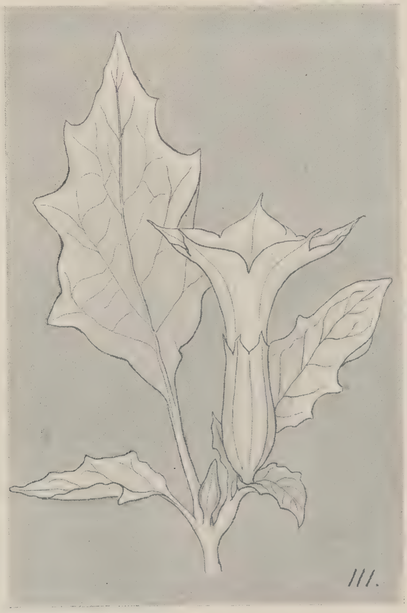


FIG. 111.—THORN-APPLE.

The corolla is bell-shaped, of a reddish-purple. The stamens are not conspicuous, as in the genus Solanum; they have distinct filaments, and are curled up in the corolla, whilst the style and stigma protrude beyond; anthers are not syngenesious. The gynæcium develops before the andrœcium, thus cross-pollination is probable. The flower is visited by humble-bees. The fruit is a black berry, projecting beyond the persistent calyx.

The *Winter-Cherry* (Physalis) has an inflated red calyx, which encloses the berry. Chili Pepper (*Capsicum*) also has a berry-like fruit.

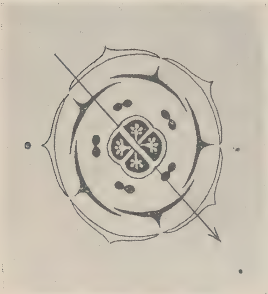


Fig. 112.—Floral Diagram of Thorn-apple.

The following genera, *Thorn-apple* (*Daturu*), *Henbane*, *Tobacco*, *Petunia*, differ from those just described in having a capsular fruit. The Thorn-apple, a common roadside weed in South Europe, is rare in England, occurring only in the South and in botanical gardens elsewhere. The oblique ovary, apparently 4-celled, should be noticed; the four chambers are due to the axile placentæ extending so far into the ovary as nearly to touch the wall of it. The fruit is a spiny capsule, dehiscing into 4 valves.

Henbane (*Hyoscyamus*) is found in waste stony places, on roadsides, or in the neighbourhood of old castles.

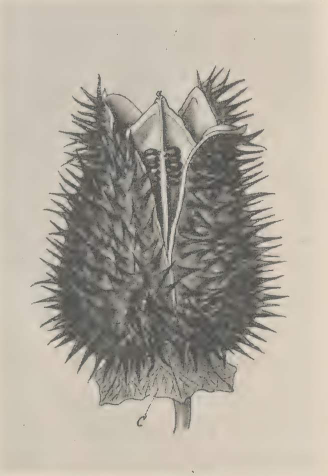


Fig. 113.—Capsule of Thorn-apple. *c*, calyx.

Characteristics of the Order.

1. Flowers usually regular, Henbane irregular.

2. Petals joined, in Bittersweet only slightly.

3. Floral leaves, except carpels, 5 in number.

4. Ovary, 2 carpels, placed obliquely.

5. Fruit, a berry or a capsule.

6. Most of the Solanaceæ are poisonous; Potato and Tomato are among the exceptions.

Distribution. This Order is chiefly tropical, and American rather than European. Valuable medicines are obtained from many of the plants in this Order.

SCROPHULARIACEÆ.

This Order is closely allied to the preceding one; the regular corolla and the oblique ovary of Solanaceæ are characters which distinguish it from the Scrophulariaceæ. On the whole, too, 5 stamens are rare in the Scrophulariaceæ, although they do occur in Mullein; in Solanaceæ 5 stamens are constant. The inflorescence differs in the two Orders (see p. 130).

The Scrophulariaceæ may be subdivided into two groups:

(*a*) The Snapdragon group, including Mullein, Figwort, Foxglove, Linaria, and Veronica. This group has been sufficiently described in "Elementary Botany," pp. 95-97, the variety in the corolla and the suppression of the stamens being the two important characteristics to note.

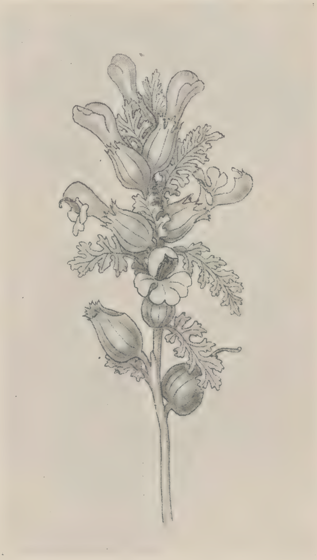


FIG. 114.—RED RATTLE.

(*b*) The Yellow Rattle group. These are semi-parasitic plants; they draw their nourishment partly from the plants on which they feed, chiefly grasses, and at the same time they have green leaves. The plants belonging to this are all herbs, and include Eyebright, Cow-wheat, Yellow Rattle, Bartsia, Lousewort, Red Rattle.

The roots of these plants attach themselves by suckers to the roots of the plants on which they feed (Fig. 116). They have bilabiate corollas, generally 4 stamens, and a capsule which dehisces along the midrib. They are, on the whole, found in marshy places. Not a single plant of this Order is good for food, and the majority are poisonous.

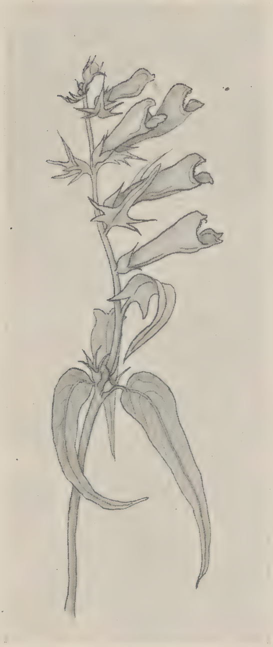


FIG. 115.—COW-WHEAT.

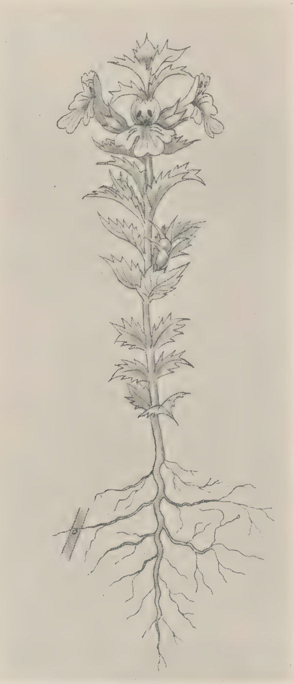


FIG. 116.—EYEBRIGHT, SHOWING ROOTS ON GRASS.

LABIATÆ.

Of the 142 genera belonging to this Order, 18 only are British; the majority belong to the Mediterranean. The genera differ comparatively little from each other; all have the following special characteristics of the Labiatæ: the square stem, the opposite leaves, the cymose inflorescence (verticillasters), the 4 nut-like fruits forming a 4-divisioned schizocarp.

The corolla and the stamens vary in the different genera. As a rule, the corolla is distinctly bilabiate. Mint and Gipsy-wort have an almost regular corolla, whilst in Bugle and Wood-sage the upper lip is either very short or wanting. The stamens are usually 4, the fifth, the posterior one, being suppressed. The Sage and Gipsy-wort have only 2. In the Sage, the structure of the stamens should be noticed, as they show a curious contrivance for cross-pollination. The stamens have very short filaments and long, slender connectives. This bears at its upper end a perfect half-anther with pollen, and at the lower end the other half-anther, which is generally empty. This last is situated at the mouth of the corolla-tube, just in the path of the insect. As the insect touches this empty anther-lobe the connective swings round at right angles, so that the upper anther-lobe, with pollen, empties itself on the bee's back. The stamens develop first in this flower, so that if the bee, when it has received the pollen on its back, goes to an old flower, the stigmas which, bending downwards, lie in the path of the bee, are cross-pollinated.

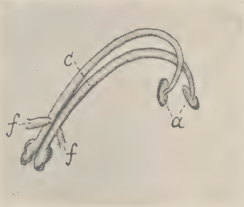


FIG. 117.—STAMEN OF SAGE. *a*, anther; *f*, filament; *c*, connective

Pollination of the Order. There seems to be some relation between the length of the corolla-tube and the number of insects visiting the flower; the number of insect visitors is less the longer the tube.

Mint and Gipsy-wort, with their short tubes, are mostly visited by flies and small insects. Thyme and Marjoram have in addition bees, which perhaps are more frequent even than flies; Betony is visited about equally by bees and flies, whilst in the genus Stachys bees are the most important visitors, and in Sage, Deadnettle, Bugle, the flowers are cross-pollinated almost exclusively by bees.

In some of the Labiatæ the stamens develop first. This may be observed in the Wood-sage (*Teucrium*). When the flower first opens the stigma is behind the two stamens, which project beyond the posterior part of the flower (there is no upper lip); then the stamens turn backwards, bending down, and the stigma now occupies the place where the stamens formerly were, and is thus cross-pollinated.

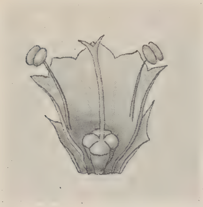


FIG. 118.—MEDIAN VERTICAL SECTION OF GIPSY-WORT.

Self-heal (*Prunella vulgaris*) has two forms of flower, one large, with both stamens and stigmas, the other small, with only pistillate flowers. Both forms are cross-pollinated, and some botanists think that the large flowers do pollinate themselves in the absence of insect visits.

TABLE OF COMPARISON.

	Boraginaceæ.	*Solanaceæ.*	*Scrophulariaceæ.*	*Labiatæ.*
Inflorescence	A one-branched cyme	Cymose with displacement of bracts	Racemose, or Cymose, or mixed	Cymose, forming verticillasters
Corolla ..	Regular	Regular	Irregular	Irregular
Stamens ..	5	5 usually, in some genera syngenesious	5, 4, or even 2,	4, or 2
Gynæcium ..	Style gynobasic; 4-celled ovary	Style terminal; Carpels in oblique plane	Style terminal; 2-celled ovary	Style gynobasic, 4-celled ovary
Fruit ..	4 achenes	A berry, or capsule	A capsule	4 achenes

AMENTACEÆ, OR CATKIN-BEARING FAMILY.

The plants of this family are shrubs or trees; they all have woody stems and form bark. The two most common kinds of bark are: 1. Scale bark, which becomes detached from the tree in thin plates, as in the Almond and Willow; 2. Ringed or Fissured bark, which is generally ruptured longitudinally and somewhat irregularly, giving the appearance of grooves or furrows, often of considerable depth, as in the Oak. It is on fissured bark that lichens and mosses mostly grow.

For the branching of Trees see "Elementary Botany," p. 24.

In Britain the majority of trees have deciduous leaves; this fact has an important influence on the undergrowth of woods, for some leaves decay much more rapidly than others, and a richer humus is thus formed. It is said that the best "leaf soil" consists of decaying Oak-leaves, and the undergrowth of the Oak is, as we have already seen, richer than that of other trees. There is a close connection between the texture of the leaf and its duration. Thin, herbaceous leaves last only one season, and drop off in the autumn; leaves of firmer texture last through the winter, only falling off when new leaves are developed, as in the Privet, or they may even last for years, as in the Holly. The mechanism producing the fall of the leaf is interesting. In some cases the leaves merely wither and drop off; in others a layer of cork cells several rows deep is formed at the point of insertion of the leaf; the middle row of this dries up, the leaf falls off, and the scar of the cork is left on the stem.

The Amentaceæ include the following Orders:

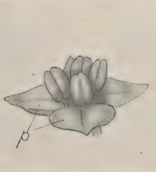
1. *Betulaceæ*, comprising the two genera Birch (*Betula*) and Alder (*Alnus*).
2. *Cupuliferæ*, comprising the Hornbeam, Hazel, Beech, Oak, Sweet Chestnut.
3. *Salicineæ*, comprising the Willow and Poplar.

These resemble each other in having deciduous leaves, catkin inflorescences, which in the case of all except the Willow and Poplar are borne on the same tree, though on different branches; the flowers are without petals, and the fruits, except in the Salicineæ, are nuts, which in the Cupuliferæ are situated in cups, called cupules.

The Betulaceæ. The *Common Birch* is easily recognised by its bark, which is silvery, giving the tree its characteristic appearance; it is scale bark, and peels off in layers. The branches are slender and peculiarly graceful; the staminate catkins hang down, whilst the pistillate ones of the same branch are above them, and catch the pollen carried by the wind from the staminate catkins of another branch. If a staminate catkin is examined it will be seen to consist of scales fairly close together, each containing three flowers; each flower shows two forked stamens. The pistillate catkins have the scales much more closely packed together, and each has likewise three flowers. The flower has no perianth, and consists of two carpels, as may be easily seen from the two styles. The fruit is a nut, which is formed in the following way: the ovary is 2-celled, and has to begin with one ovule in each cell; then one cell and one ovule become suppressed, the other ovule developing into a seed. The wall of the ovary becomes hard. Each scale of the pistillate catkin thus supports three broadly-winged nuts, formed from the three flowers; the wings of the nuts are organs of dispersion.

The *Alder* is a much darker tree than the Birch, and usually grows by streams or in wet woods and pastures. The staminate catkins are two or three together, and hang down; the pistillate ones of the same branch are above them in short erect spikes. After the fruit is formed the scales become hard and woody, and remain on the tree during the winter—at any rate, long after the nuts have fallen (Plate VIII., Fig. 120).

122



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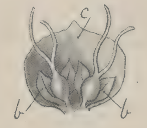

Fig. 122.—Staminate Flower, Alder. *p*, perianth.

Fig. 123.—Pistillate Flower, Alder. *c*, scale covering 2 flowers; *b*, scales belonging to flower.

Each staminate flower consists of a perianth and 4 stamens, the whole being situated, with two other flowers of similar structure, in a scale.

Fig. 123 shows two pistillate flowers situated in a scale (*c*); each single flower has 2 bracts, and consists of 2 carpels, as may easily be seen from the 2 styles.

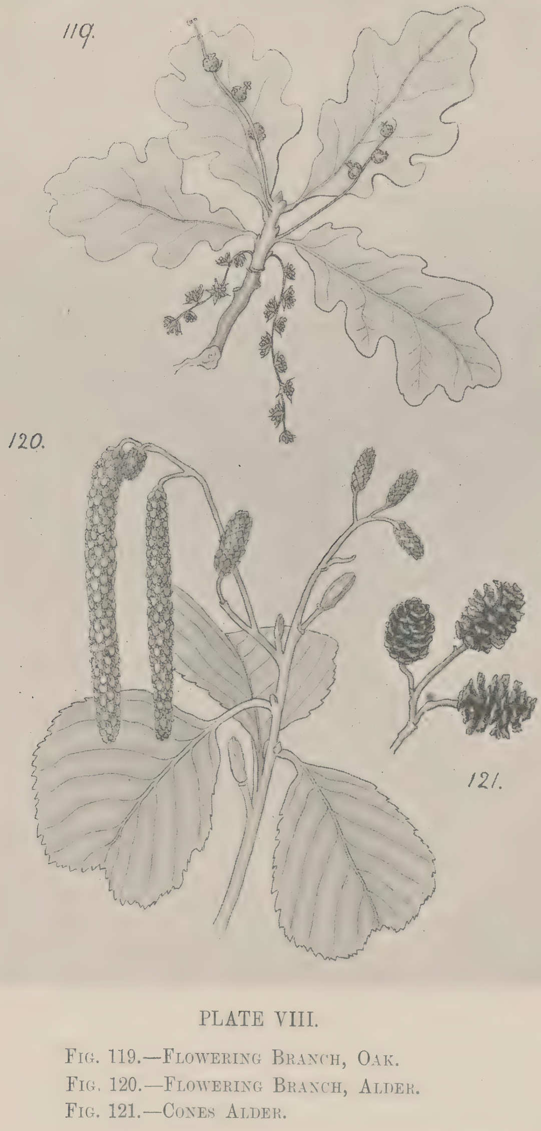

PLATE VIII.

Fig. 119.—Flowering Branch, Oak.
Fig. 120.—Flowering Branch, Alder.
Fig. 121.—Cones Alder.

In the majority of species of Alder both sets of catkins are developed the year before they flower, and bloom before the leaves.

The Cupuliferæ. The distinctive feature of the Cupuliferæ is the *Cupule*, in which the nut is situated. This is formed from the bract-like scales which invest the flower. It varies considerably in each genus of the Order; thus in the Hornbeam, instead of being cuplike, it has the form of a large three-lobed, leaf-like scale, the nut being situated at its base. In the Hazel it is more the shape of a cup; it is leathery in texture, but not nearly as hard as that of the Acorn, and is far smaller than the leaf-like envelope of the Hornbeam; it spreads out at its edges, exposing the nut inside. In the Beech the cupule entirely encloses the nuts, and when ripe bursts into four valves. The cupule of the Acorn is cuplike, and too well known to need description. That of the Sweet Chestnut is extremely prickly, and like that of the Beech, also bursts into valves.

The *Hornbeam* is not a very tall tree, and has numerous short branches. The staminate flowers are in catkins, with broad, sessile scales, but there is no perianth; there are about twelve stamens to each scale. The pistillate flowers occur two together within each scale, and have a superior perianth; each flower has two carpels.

The *Beech* is one of the most beautiful of English trees. Its trunk is smooth and straight, its bark also smooth and dark. Sometimes the branches begin low down, but often not until a fair height is reached. Its buds are very thoroughly protected with brown scales, at least 12 in number, closely overlapping each other. It is one of the first trees to burst its scales in spring, and there is hardly anything more delicate in colouring than the first green leaves of the Beech with their ciliate margin.

The staminate flowers of the Beech hang down in long stalked tassels. Each flower has a 4- to 6-lobed perianth containing 8 to 12 stamens. The pistillate flowers have an involucre of bracts forming the cupule; the ovary is 3-celled, each cell containing 2 ovules, but as a rule only two or three nuts develop. There is suppression of parts, as there generally is in the formation of nuts.

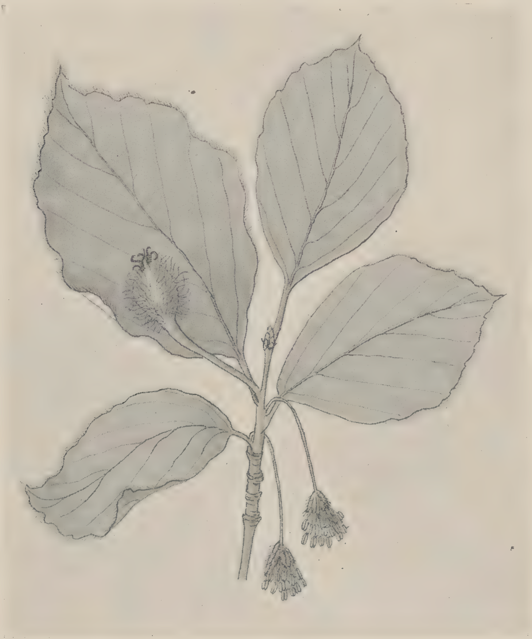

FIG. 124.—FLOWERING BRANCH, BEECH.

The *Oak* has a gnarled trunk; its branches are twisted, its bark fissured. There are about 100 different species of Oak in Britain, the most common being *Quercus robur*, which produces leaves and acorns on rather long stalks. It grows to a great height, 150 to 180 feet, and lives for 600 or even 1,000 years.

The inflorescence of the Oak is shown in Plate VIII., Fig. 119. The staminate flowers are in long catkins, which hang down; the catkin scales are very small. There are 6 to 12 stamens in each flower; the perianth is irregular. The pistillate flowers are solitary, or occurring in clusters of 2 or 3. The involucre of bracts forms the cupule of the fruit. The perianth adheres to the ovary, which is 3-celled, with 2 ovules in each cell. As a rule only 1 ovule (at the most 2) is developed in each flower; first 1 ovule in each cell is suppressed, then 1 of the remaining 3 grows at the expense of the other 2.

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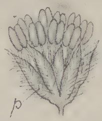

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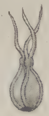

FIG. 125.—STAMINATE FLOWER, BEECH.
p, fringed perianth.

FIG. 126.—PISTILLATE FLOWER, BEECH.

The structure of the *Hazel* is very similar to that of the Oak; there are 8 stamens instead of 12, and the cupule is leafy, forming the well-known "husk" of the nut ("Elementary Botany," Plate III., Fig. 58).

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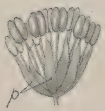

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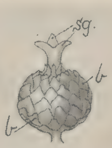


FIG. 127.—STAMINATE FLOWER, OAK.
p, perianth.

FIG. 128.—PISTILLATE FLOWER, OAK.
b, bracts forming cupule; *sg*, stigmas.

In the *Sweet Chestnut* the spiny cupule described above should be noted; the flowers closely resemble those of the Oak, except that the perianth of the staminate flowers is more developed than in those of the Oak.

Salicineæ. The staminate and pistillate flowers are on different trees; thus cross-pollination is probable. Willows are pollinated by insects, Poplars by wind. For the structure of Willow catkins see "Elementary Botany," Figs. 55 to 57.

The *White Poplar*, which grows along streams and in open moist woods, has a light grey or ash-coloured bark; the leaves and young shoots are covered with a white, cottony substance.

The bracts of the staminate flowers are jagged at the top (Fig. 130, *b*). Both staminate and pistillate flowers have perianths; the stamens are 8 in number, the carpels 2.

The fruits of the Salicineæ are capsules, with hairy seeds.

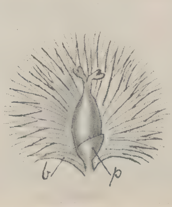
In observing trees, the following characters should be noted:

1. The general growth, especially the branching, which is best observed in winter.

2. The position of the leaf-buds and flower-buds, and their relation to the shape of the tree.

3. The bark, kind and colour.

129



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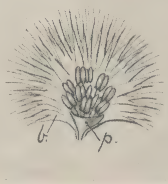


FIG. 129.—PISTILLATE FLOWER, POPLAR.
p, perianth ; *b*, fringed bract.

FIG. 130.—STAMINATE FLOWER, POPLAR.
p, perianth ; *b*, fringed bract.

4. The shape of the leaves, and advantage of such shape. The angle at which light falls on the leaf.

5. The inflorescence: the differences in staminate and pistillate inflorescences—whether pendulous or upright; whether on the same tree or on different trees; on the same branch or different branches.

6. The structure of the winter buds—protection against cold, etc.

7. The time of flowering—whether before the leaves or not.

ORCHIDACEÆ.

This is a Monocotyledonous Order, and has the usual parallel veins and the floral leaves in whorls of 3.

Type. EARLY PURPLE ORCHIS (*Orchis mascula*).

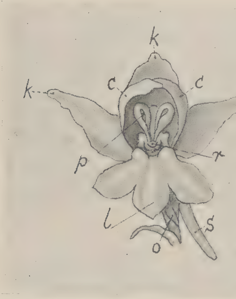
Rootstock: the underground stem each year forms a new tuber by the side of the decaying one of the previous year; from this new tuber arises the stem of the following year.

Leaves: radical, rather broad, and often spotted.

Inflorescence: a spike.

Flowers: reddish purple, irregular and epigynous.

131



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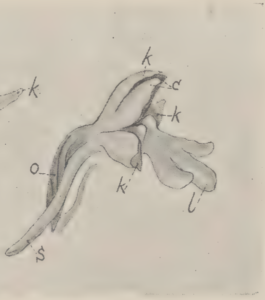

Fig. 131.—Flower of Orchis (Front View).
Fig. 132.—Flower of Orchis (Side View).

l, labellum; *o*, ovary; *p*, pollinia; *s*, spur of labellum; *r*, rostellum; *k*, sepals; *c*, anterior petals.

Structure of Flower. Perianth, 3 + 3. The outer whorl consists of 3 petaloid leaves, the inner also of the same number. The largest leaf of the inner whorl forms a lower lip, and appears to be on the anterior side of the flower; it is prolonged into a spur (Fig. 131, *s*), secretes nectar, and is called the labellum (*l*).

The peculiarity of the structure of an Orchid is that the andrœcium and gynæcium are united to each other, the stamen being combined with the style, forming what is called the column. Only one stamen is developed. The anther is 2-lobed, and the pollen grains found in each anther-lobe are united into masses, called pollinia. The best way to see this is to take a pencil with a sharp point and put it into the spur. The pencil must touch a little pouch-like organ, exactly opposite the labellum and projecting into the gangway of the nectary; this is the rostellum (Fig. 131, *r*). Into this rostellum the discs of the pollinia fit; consequently, as the pencil touches the rostellum, the pollinia adhere to it, and when the pencil is withdrawn one or both pollinia may be seen on it.

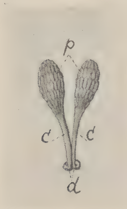

FIG. 133.—POLLINIA OF ORCHIS.

c, stalk ; *d*, disc ; *p*, pollen grains forming masses.

Each pollinium consists of a stalk, which bears the pollen masses, and at the opposite end it terminates in a disc, which fits into the rostellum.

The remaining stamens are suppressed; their position is indicated in the floral diagram. Judging from other Monocotyledonous Orders, the number of stamens would be 6, and Darwin has shown clearly that there are traces of 6 in the Orchid (Fig. 134).

The gynæcium consists of 3 carpels, with 3 parietal placentæ; the ovary is twisted, and it is this that makes the true posterior side of the flower appear to be anterior. The style unites with the stamen, as mentioned above; 2 stigmatic surfaces are easily seen just beneath and on each side of the anther; whilst it is considered that the rostellum, into which the discs of the pollinia fit, is a modified stigma.

The fruit is a capsule, dehiscing by 3 valves; the seeds are small and light, and scattered by the wind.

In the floral diagram (Fig. 134) it must be noticed that the parts of the flower are represented in their true positions, the labellum on the posterior side, the single stamen on the anterior, etc.

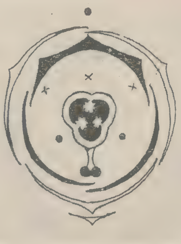

FIG. 134.—FLORAL DIAGRAM OF ORCHIS.

Pollination. The labellum serves as a landing-place for the insect, which pushes its head into the chamber leading to the nectary. Projecting into this chamber is the rostellum, which must therefore be touched by the insect. As the insect touches the rostellum its outer membrane is ruptured, and the discs of the pollinia, which fit into the pouch of the rostellum, being sticky, adhere to the insect's proboscis, and are carried to another flower. When the pollinia are first removed from the anther they are erect on the proboscis, but in the course of thirty seconds they fall through an angle of 90 degrees; so that by the time the insect reaches a second flower they are hanging down, and are in such a position as to come in contact with the stigmatic surfaces on each side of the rostellum, and thus the second flower is cross-pollinated. Were it not for this contrivance, the pollinia would merely touch the anther of the fresh flower, and would not cross-pollinate it at all. There is another provision of Nature that should be noticed: the stigmatic surfaces are sticky or viscid, but only sufficiently so to break the elastic threads which hold the pollen grains together; if they were more sticky, the whole pollinium would be pulled off from the insect; but as it is, only a few grains are taken by each flower, so that one pollinium can cross-pollinate several flowers.

Darwin found that the majority of Orchids were cross-pollinated; the Bee Orchid, however, pollinates itself. The chief points of difference in the structure of this species are: The anther opens of itself as soon as the flower is fully expanded, and does not require any pressure on the rostellum to liberate the pollinia; then owing to the stalks being very slender and flexible, when the pollen masses fall out on the opening of the anther, the stalks hang freely in the air, and the pollen masses are in a position to strike the stigma. Darwin covered up a Bee Orchid with a net, in order to prevent insects getting to the plant, and was able to watch the exact movements of the pollinia. These differences in structure account for the fact that the Bee Orchid pollinates itself.

Genera. The largest British genus is *Orchis*, which includes several species, such as Early Purple, Spotted, Pyramidal, Marsh, etc. They all have a spur.

The genus *Habenaria*, which includes, among others, the

Butterfly and the Frog Orchids, is also spurred. The Butterfly is very sweet-scented, and has particularly long spurs; the Frog is green.

The genus *Ophrys* differs from those just mentioned in having no spur. This includes the Bee, the Spider, and the Fly Orchids.

The genus *Neottia*, the Bird's-nest Orchid, is so named from its rootstock, which consists of a dense mass of thick, rather succulent, fibres twisted in and out like a bird's nest. It is pale brown in colour, and a very good example of a saprophyte.

The genus *Cypripedium*, or Lady's Slipper, must be mentioned, as it has 2 stamens. It consists of a single British species, found only in Durham and Yorkshire.

The genus *Listera*, Twayblade, is easily recognised by its two broad ovate leaves, about 6 inches from the ground. The other species, with small cordate leaves, is a much more slender plant, belonging to mountain regions.

Ecology. Orchids abound in the tropics, where they are generally epiphytic. Their aerial roots either adhere to the bark of the supporting tree, securing the plant in its position, or they may hang loose in the air.

IRIDACEÆ.

Type. Yellow Flag (*Iris Pseudacorus*).

The Iris has an underground stem, which creeps along horizontally. The leaves are mostly radical; the cauline leaves are arranged on opposite sides of the stem, and fit into each other, the outer bestriding the inner, somewhat in the same way as a rider sits astride the horse; hence these leaves are said to be equitant (Lat. *equitare* = to ride).

The flowers are borne in the axils of the leaves, two or three together, in this species. They are epigynous, the perianth is petaloid, and the inner whorl of stamens is suppressed.

Structure of Flower. *Perianth:* 3 + 3, superior; the leaves are united and form a tube.

Andrœcium (stamens): 3 + 0, free, epigynous, opposite the outer perianth whorl.

Gynæcium: carpels 3, joined, inferior.

The style is single below, but divides in its upper part into 3 petaloid branches, which bend over the stamens. The stigmas look like little flaps just above the stamens. It must be noticed that the stamens are opposite the carpels; this is one reason for thinking that the 3 inner stamens are suppressed, for in other Monocotyledons, such as the snowdrop and the Lily, where there are 6 stamens, it is found that the 3 outer stamens are opposite to the carpels, whilst the 3

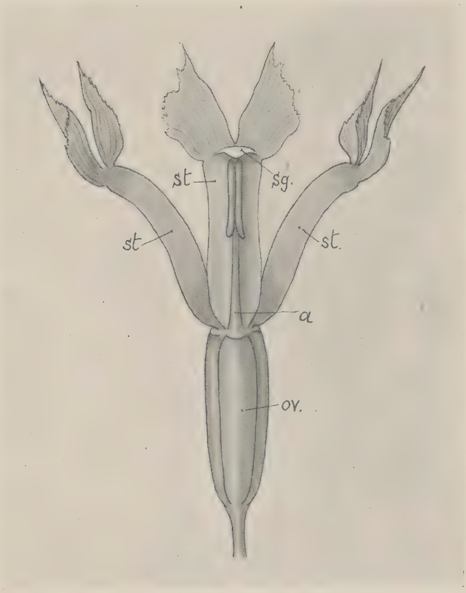

FIG. 135.—IRIS WITH PERIANTH REMOVED.

a, stamen; *ov*, ovary; *sg*, stigma; *st*, petaloid styles.

inner alternate with them. The ovules are borne on axile placentæ.

The fruit is a capsule, dehiscing along the midrib.

Pollination. As the honey is deeply seated, only insects with long probosces can reach the honey at the bottom, and they can only reach it by the narrow passages between the base of the stigmatic lobes and the outer perianth leaves. When creeping in, to push their probosces into these passages, the back of the insect touches the stigma (Fig. 135, *s*), depositing on it the pollen brought from another flower. As the anthers lie under the stigmas, self-pollination is impossible.

Chief Genera. 1. *Iris.*

2. *Crocus.*—For structure of corm, see "Elementary Botany," p. 21. The stigmas are fringed, but not petal-like, as in the Iris.

3. *Gladiolus.*—The inflorescence is a one-sided spike. The perianth is oblique, and its leaves almost form two lips. The stigmas are 2, not 3.

This Order may be compared with two other Monocotyledonous Orders, Liliaceæ and Amaryllidaceæ (Snowdrop). It differs from Liliaceæ in the inferior ovary, and from both Liliaceæ and Amaryllidaceæ in the suppression of the inner whorl of stamens.

LILIACEÆ.

This Order has been so fully discussed in the "Elementary Botany" that here only a few notes on its ecology are given.

The Liliaceæ are most abundant in warm climates, such as the Mediterranean, the Steppes of Asia, and South Africa. The British genera are for the most part bulbous plants; many of the tropical species have woody stems.

Among the British genera, Herb Paris, Solomon's Seal, Lily of the Valley, Butcher's Broom, Bluebell, belong to woods; some few are sea plants, such as the Spring Squill (*Scilla verna*), which is found on the cliffs of South Cornwall, and Sand Leek; whilst the Bog and Scottish Asphodel are hydrophytic in habit.

GRAMINEÆ.

External Characters. Grasses are easily recognised and distinguished from all other plants by certain external characters.

1. The stem, if cut across, is usually circular in outline; it is also hollow, except at the nodes. At the node a swelling may be seen; this is a pulvinus. If grass is trampled on or beaten down by rain it becomes "laid"; then the lower side of the pulvinus elongates, and brings all the part of the grass above it into an erect position.

2. The leaves are arranged in two rows alternately. Each leaf consists of a blade, which passes directly without a leaf-stalk into a sheath. At the junction of the blade with the sheath there is an outgrowth of the blade called the ligule; its function is probably to prevent the water which has run down the leaf getting into the sheath and rotting the stem. The sheath is nearly always split, and the leaves are usually elongated in form (Plate IX., Fig. 136).

3. The roots of Grasses are usually fibrous, arising from the nodes. Grasses may be annuals, biennials, or perennials. If all the shoots have flowering stems of this year's growth, then the Grass is an annual; if it has leaves only, it may be an annual or perennial; the latter will probably have more leaf-scars than the former.

The only plants with which Grasses could possibly be confused are Sedges and Rushes. The former have solid angular stems, with leaves in three rows; the latter are generally readily distinguished by their cylindrical leaves, and always by the membranous perianth of the flowers.

The inflorescence of a Grass consists of a principal stalk, called a "haulm" or "culm," on which shorter stalks are arranged. Each short stalk bears a spikelet, consisting of scale-like structures, in the angles of which are situated the flowers. The inflorescence of a Grass, such as Wheat or Oat, consists of several spikelets placed more or less closely one above the other. If a spikelet is removed and examined it will be seen to consist of the following structures: On the outside of all 2 large scales, one just below the other; these are called the outer and inner glumes (Plate IX., Fig. 139, *o*). These enclose all the flowers of the spikelet. When they are removed (and care should be taken to remove only the glumes), there will usually be seen 3 other pairs of scales, more delicate than the glumes; these are the pales (*paleæ*); each pair encloses a flower. The outermost pale is at the base of the flower-stalk, and is the larger of the two, and bears an arm, whilst the inner pale is smaller and rather higher up the stalk, nearer the flower. A fourth pair of pales is usually found at the extreme end of the principal stalk, but these do not enclose a flower (see Fig. 139).

To sum up, a spikelet usually consists of:

1. An outer and inner glume.
2. Four pairs of pales, three enclosing flowers, the terminal one without a flower.

Structure of Flower. The parts of a flower are shown in Fig. 137. The pales are seen removed; then comes the flower proper. This consists of 3 stamens, which have slender filaments and versatile anthers, so that the stamens hang down when fully developed, and the pollen is therefore easily scattered. The most conspicuous part of the gynæcium are the 2 plume-like stigmas, which would lead one to expect 2 carpels, but it is clear from the development of the ovary that there is but 1 carpel.

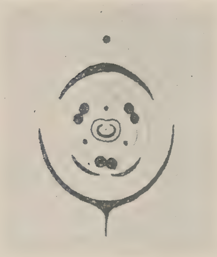

FIG. 140.—FLORAL DIAGRAM OF A TYPICAL GRASS.

There is no perianth, though just below the stamens 2 little scales, called lodicules, may be seen. These are probably of the nature of bracts, not floral leaves; their function is to push apart the pales when the flower is mature.

So far a typical Grass has been described, but all Grasses have not necessarily 3 flowers in a spikelet; the number varies very much, and there are also Grasses in which some spikelets contain only stamens, others only a gynæcium.

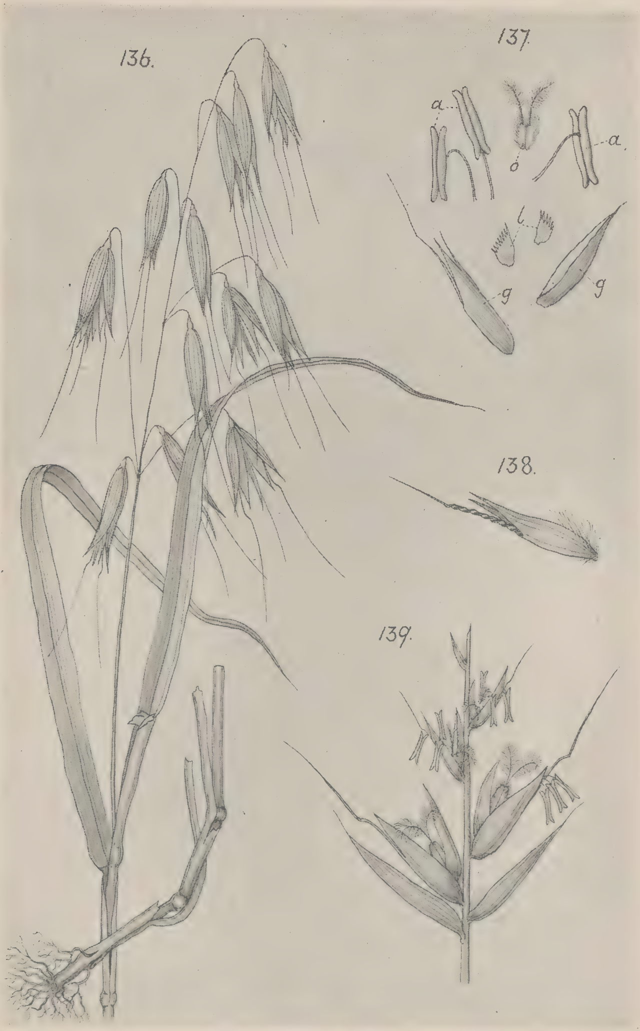

PLATE IX.

FIG. 136.—OAT.

FIG. 137.—DIAGRAM OF A SPIKELET OF OAT.
g, pales; *l*, lodicules; *a*, anther; *o*, ovary.

FIG. 138.—"GRAIN" ENCLOSED IN GLUME.

FIG. 139.—DIAGRAM OF INFLORESCENCE.

Pollination. The plume-like stigmas protrude as soon as the pales open, and as the pollen is borne by the wind, it is quite easy for them to catch the pollen. In some Grasses the stigmatic plumes are ready for pollination before the anthers are ripe, so that cross-pollination can take place.

The pollen grain puts out its tube, which makes its way down between the cells of the stigma to the embryo sac of the ovule; fertilisation takes place, and the embryo begins to develop. The endosperm becomes laden with starch grains or sugar; the ripe seed soon fills the ovary, and its wall becomes fused with that of the carpel, giving rise to the "grain," which is thus technically a fruit, not a seed. The embryo consists of radicle, plumule, and scutellum; the rest of the grain is filled with endosperm. The germination of a Grass, such as Maize, is given in the "Elementary Botany," p. 5.

Ecology of the Order. Professor Marshall Ward, in his "Handbook on Grasses," thus classifies them according to habitat:

1. Meadow and Pasture Grasses.
2. Shade Grasses.
3. Aquatic and semi-aquatic Grasses.
4. Moor and Heather Grasses.
5. Seaside Grasses.
6. Ruderal or Vagabond Grasses.

The first two classes are mesophytic, the third hydrophytic, the fourth and fifth xerophytic, whilst the sixth class, as the term "vagabond" implies, is the most adaptable; it includes, in fact, many species of the former classes, for a "vagabond" grass will flourish in a variety of conditions.

If the leaves of these different classes are compared, it will be noticed that shade grasses have, as a rule, flat leaves, with a thin epidermis; in texture they are thin and herbaceous. Maritime grasses have narrow, upright, grooved or folded leaves, with a thick cuticle and water-storage tissue; they are hard and leathery in structure. Leaves of moor grasses are, on the whole, hairy, though not so hairy as those of maritime grasses. The hairiness of the same species will vary with habitat.

Grasses may, to some extent, indicate the presence of certain soils. As a rule, they avoid chalk; where Psamma or Elymus is found there is probably plenty of salt in the soil, as at the seaside; others indicate a sandy soil; others, again, the existence of much humus.

Lastly, the various adaptations for the dispersion of the seeds (fruits) should be noticed. Some are so light that they are easily taken by the wind; in other cases the glumes serve as "wings." Sometimes the stalk of the spikelet, which comes away with the fruit, is furnished with fine silky hairs, which act as an organ of dispersion, whilst those with awns are caught in the wool and fur of sheep and other animals, and are thus dispersed. The awn may develop in a variety of ways. Sometimes it is plume-like at its upper end and twisted at its base, which is more or less hard. The plume-like portion helps to drive it through the air, whilst the harder portion of the base serves to fix it in the soil (Fig. 138).

There is no Order that is more universally distributed or more useful to man. Not only do some yield special articles of food, such as Wheat, Oats, Barley, Maize, Sugar-cane; but the fact that every blade of grass all the world over is, under the influence of sunlight, engaged in storing up carbon and building up food substance, which in its turn ministers to the life of the animals on which man feeds, shows how important this Order is, from the economic point of view, to mankind.

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APPENDIX A

LABORATORY WORK

A FEW suggestions may be helpful to those students working along.

I. *The Use of the Microscope.*—The flat table, as it were, almost in the centre of a microscope is called the ‘stage.’ Beneath this is the mirror that reflects the light on to the stage. Above the stage is the tube of the microscope, which can be drawn out. At the end of the tube furthest from the stage the eye-piece fits, whilst at the other end of the tube, that nearest the stage, the magnifying powers are screwed in.

The object to be examined is placed on a glass slide, which is put on the stage. The mirror is arranged so as to reflect the light on to the object, and the observer focuses the draw-tube until he can see the object distinctly. Beginners should always work with low magnifying powers at first, such as a 2-inch or 1-inch. In this case the draw-tube has not to be very near the object, and is brought into focus by turning the two wheels attached to the tube, one on each side. If a high power, such as $\frac{1}{4}$ or $\frac{1}{6}$ inch, is used, then the power has almost to touch the glass slide. It is brought into exact position by using the smaller wheel, which will be seen at the back of the microscope, lower down than the two bigger wheels. This smaller wheel should only be used with high powers, and not until the object has been brought into focus by the use of the larger wheels, which constitute what is called the coarse adjustment, the smaller wheel being the fine adjustment.

II. *Preparation of Objects for the Microscope.*—When unicellular organisms, such as Protococcus, are being examined, they are generally put on the glass slide in a drop of water, being taken up by means of a glass tube narrowed out at one end, called a pipette. The finger should be kept over the broad end of the pipette when it is being lifted out of the water. The drop of water with the Protococcus or other organism having been put on the glass slide, a thin circular (or square) piece of glass called a cover - glass is placed over it. The cover - glass should be held between the thumb and forefinger of the left hand; its edge should just touch the slide at the outer limit of the water, and then by means of a needle it is gently lowered, being thus gradually wetted, the water at the same time spreading out into the thinnest layer possible. In this way air-bubbles are avoided, whereas if the cover-glass is simply dropped down, it is difficult to see anything clearly on account of the air-bubbles. It takes a little practice to put down cover-glasses well.

If it is desired to stain the organisms in the drop of water (p. 42), it is best to do so after the cover-glass has been put on. A small strip of blotting-paper is placed against the left-hand side of the cover-glass; a drop of stain (iodine is often used) is taken up on a glass rod and applied to the opposite edge of the cover-glass. The blotting-paper (or filter-paper) sucks up some of the water, thus creating a current, and the stain is drawn in.

If the object to be examined under the microscope is several layers of cells thick, such as a stem or leaf, a section must be cut. If the substance is hard, as a stem, it can be held firmly in the left hand. The surface is cut as smoothly as possible, and with a sharp razor a very thin slice is made. It takes considerable practice, in cutting sections, to get very thin, even slices. When even, the section lies flat on the slide, but if uneven, it will not be flat, the cover-glass will not lie evenly on it, and it will not be possible to examine it with a high power. In cutting sections, the blade of the razor must be kept wet, and it should be drawn towards the person, not in the opposite direction; it should be kept as flat as possible. When the section that is being cut is really thin, it is possible to see the colour of the steel as the razor is drawn through the substance.

If a thin substance like a leaf is to be cut, it must be put between something solid. The pith of elder is generally used; a piece of carrot will do. The leaf is put between two pieces of pith or carrot. A thin section is cut of the pith or carrot, and the leaf is cut at the same time.

Sections are often stained in order to bring out the outlines of the cells more clearly. For this purpose some aniline dye, such as gentian blue or methyl violet, is often used. (There are special stains for special purposes; thus the structure of a sieve-plate is best brought out by eosin.) Two or three drops of the stain are put into a watch-glass containing water. The solution should be faint rather than dark-coloured, as too deep staining of a section conceals instead of making the cells clearer. The section is placed in the solution, left for five or ten minutes, according to the strength of the solution, then it is put into another watch-glass containing only water, so as to wash off any outside stain; then a drop of glycerine is placed by means of a glass rod on the slide, and the section put into the glycerine, and covered with a cover-glass. The section throughout the process of staining is lifted by means of needles, or an instrument called a lifter may be used.

Glass slides, glass rods, cover-glasses, dyes, lifters, pipettes, needles fixed in handles, pith of elder, etc., can be bought from any microscope dealer, and are inexpensive. With care the same set of slides, etc., lasts for years.

APPENDIX B

SPECIMEN ECOLOGICAL OBSERVATIONS

I. List of Water-Plants obtained from Coombe Hill Canal, Gloucestershire, by the Cheltenham College Natural History Society, and kindly supplied me by Mr. G. W. Hedley.

DICOTYLEDONS.

Common Name.	*Technical Name.*	*Natural Order.*
Celery-leaved Ranunculus	*Ranunculus scleratus*	Ranunculaceæ
Water Crowfoot	,, *aquatilis*	
Marsh Watercress	*Nasturtium amphibium*	Cruciferæ
Great ,,	,, *palustre*	
Common ,,	,, *officinale*	
Water Starwort	*Stellaria aquatica*	Caryophyllaceæ
Bog ,,	,, *uliginosa*	
Square-stalked St. John's Wort	*Hypericum quadrangulum*	Hypericineæ
Purple Loosestrife	*Lythrum salicaria*	Lythraceæ
Water Dropwort	*Œnanth fistulosa*	Umbelliferæ
Fine-leaved Œnanth	,, *phellandrium*	
Water Parsnip	*Sium latifolium*	
Lesser Sium	,, *angustifolium*	
Common Bladderwort	*Utricularia vulgaris*	Lentibulaceæ
Forget-me-not	*Myosotis palustris*	Boraginaceæ
Water Figwort	*Scrophularia aquatica*	Scrophulariaceæ
Gipsywort	*Lycopus Europæus*	Labiatæ
Water Mint	*Mentha aquatica*	
Marsh Stachys	*Stachys palustris*	
Common Skullcap	*Scutellaria galericulata*	
Water Dock	*Rumex hydrolapathum*	Polygonaceæ
Golden ,,	,, *maritimus*	
Amphibious Polygonum	*Polygonum amphibium*	
Common Callitriche	*Callitriche aquatica*	Callitrichineæ

MONOCOTYLEDONS.

Common Name.	*Technical Name.*	*Natural Order.*
Bur-reed	*Sparganium ramosum*	Typhaceæ
Simple Sparganium	,, *simplex*	
Lesser Duckweed	*Lemna minor*	Lemnaceæ
Ivy-leaved ,,	,, *trisulca*	
Greater ,,	,, *polyrrhiza*	
Water Plantain	*Alisma plantago*	Alismaceæ
Flowering Rush	*Butomus umbellatus*	
Common Arrowhead	*Sagittaria sagittifolia*	
Common Frogbit	*Hydrocharis Morsus-ranæ*	Hydrocharideæ
Sweet Flag	*Iris pseud-acorus*	Iridaceæ
Creeping Scirpus	*Scirpus palustris*	Cyperaceæ
Carex	Many species	
Reed Digraphis	*Digraphis arundinacea*	Gramineæ
Floating Poa	*Poa fluitans*	

The above list shows that the habit of a plant is independent of its Natural Order (p. 5). The thirty-eight plants here enumerated belong to no less than nineteen different Orders.

It should also be noticed that more than one-third are Monocotyledons (p. 31).

II. Observations on Woods at Birdlip, Gloucestershire, by Cheltenham Ladies' College Field Club.

Date.—May 23.

Time.—Two hours.

Number of Girls.—Ten. Under the guidance of a teacher of botany and a teacher of geology.

Method.—The nature of the observations to be made was explained some days before, and each girl was required to bring a copy of the ordnance map of the area to be investigated and a notebook. Only those who knew the names of common plants were allowed to take part in these observations. Having arrived at the wood, an area was selected, and each girl outlined this in her map. Then the aspect was roughly determined by observation of the sun; the general appearance of the selected area, its slope, the nature of the soil, were all noted and entered on the spot in the notebooks. Next the dominant species was determined, then the girls dispersed over the given area, picking one specimen of each plant forming the undergrowth. A list was then made by comparing all the plants gathered: (1) of secondary shrubs, if any; (2) of herbs forming the undergrowth.

Three different areas were investigated on May 23. These may be called A, B, and C.

A was about three-quarters of an acre in extent, its aspect

W.S.W. The ground sloped very much, and the soil consisted of limestone detritus from the oolite above, which here covers the Upper Lias clays. The dominant species was Beech. The trees were young, placed one to two yards apart. There were no secondary shrubs. The upper part of the slope was bare, having an undergrowth of moss and a few herbaceous plants scattered about. The lower part was more exposed to the sun, and was somewhat grassy.

The undergrowth included about 40 species, the most plentiful being Hawkweeds, Hemp Agrimony, Chickweeds (Cerastium), Cress (Lepridium), Speedwells, and the Orchids, Twayblade and White Helleborine.

B. Area, an acre; aspect, S.W. The dominant species was Beech, but in this part of the wood the trees were much older, and beneath them there was a thick carpet of leaves. The general appearance was bare, except where Bluebells formed a dense outgrowth. In those parts where the beech mould was thick Wood Anemones and Lesser Celandines were abundant.

The undergrowth consisted chiefly of early flowering plants (p. 29), and here and there a Bird's-nest Orchid was found (p. 19).

On the whole, there were fewer species found in B than in A.

C. The area selected was along the fringe of the wood. The soil was oolitic limestone, the aspect S.W. It was a very steep, rough bit of ground with loose rocks. It was impossible to decide without more exact and lengthy observation on the dominant species. The Ash and White Beam-tree seemed to occur in about equal numbers. Among secondary shrubs may be mentioned the Hawthorn, Guelder-rose, Raspberry, Blackberry. The undergrowth was very luxuriant, including some sixty species. This richness of undergrowth would be due to the greater amount of light available at the outskirts of the wood.

On June 27 further ecological observations were made by the same girls as before at Birdlip in a different part of the wood from that observed on May 23.

A larger area, about two and a half acres, was taken, and about one and a half hours spent in it. The method pursued was as before.

The dominant species was Mountain Ash, the trees being mostly quite young. The secondary species were numerous, including Elder, Hawthorn, Dogwood, Hazel, Guelder-rose, Dog-rose, Bramble, and along the fringe of the wood Sycamores, Maples, a few Firs, and still fewer Larches.

The herbaceous undergrowth was luxuriant, consisting of about fifty species, the most interesting of which were Belladonna, Fly Orchis, Spotted Orchis, Cephalanthera, Hound's-tongue, Large Willow-herb, Rock-rose, St. John's Wort, Enchanter's Nightshade, Wild Strawberry.

An opportunity of observing the growth on humus occurred. On a small trunk of a cut-down tree, covered with leaf-mould and shaded by a Mountain Ash, the following were found: Mosses and Lichens in abundance, Strawberry, Geum, St. John's Wort, Germander Speedwell, Chickweed, and this in an area of about 2 square feet.

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